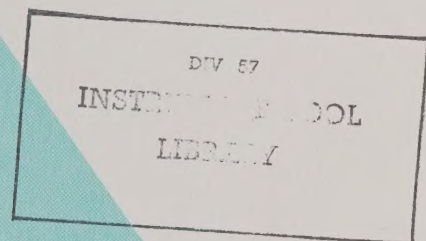
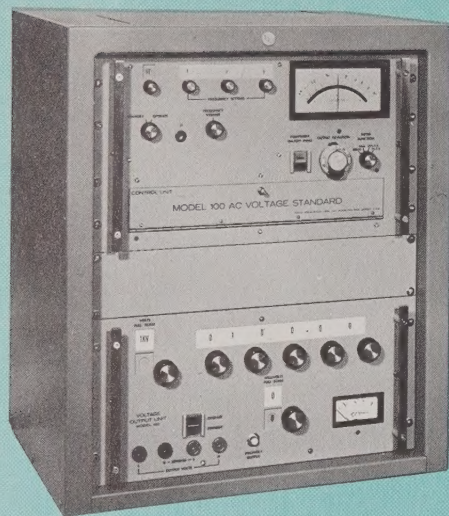
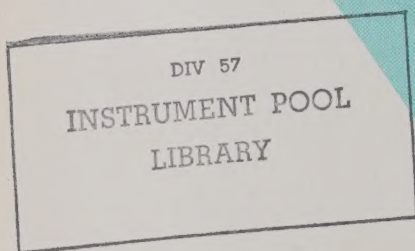


Model 100 System



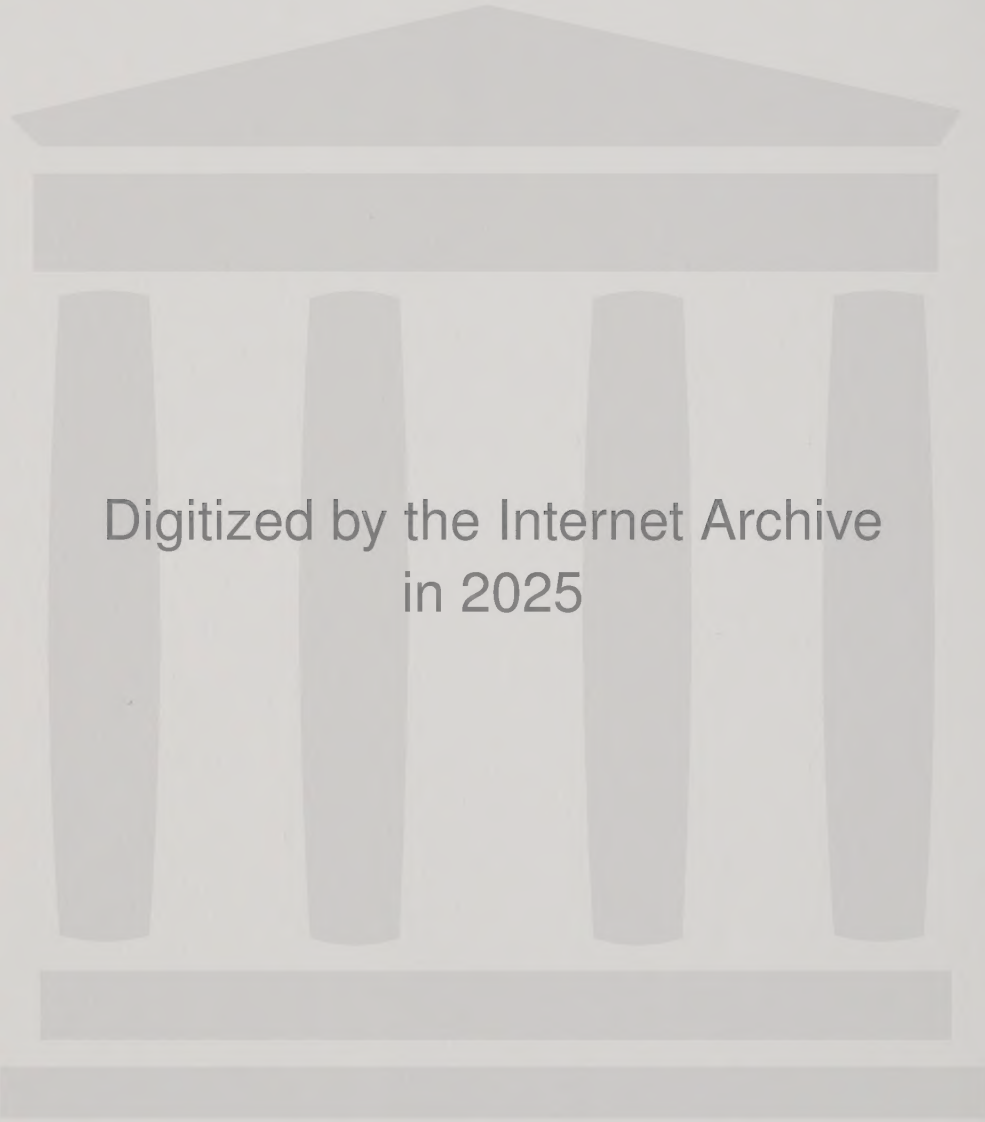
AC VOLTAGE STANDARD

AC CURRENT STANDARD



MANUAL OF INSTRUCTIONS





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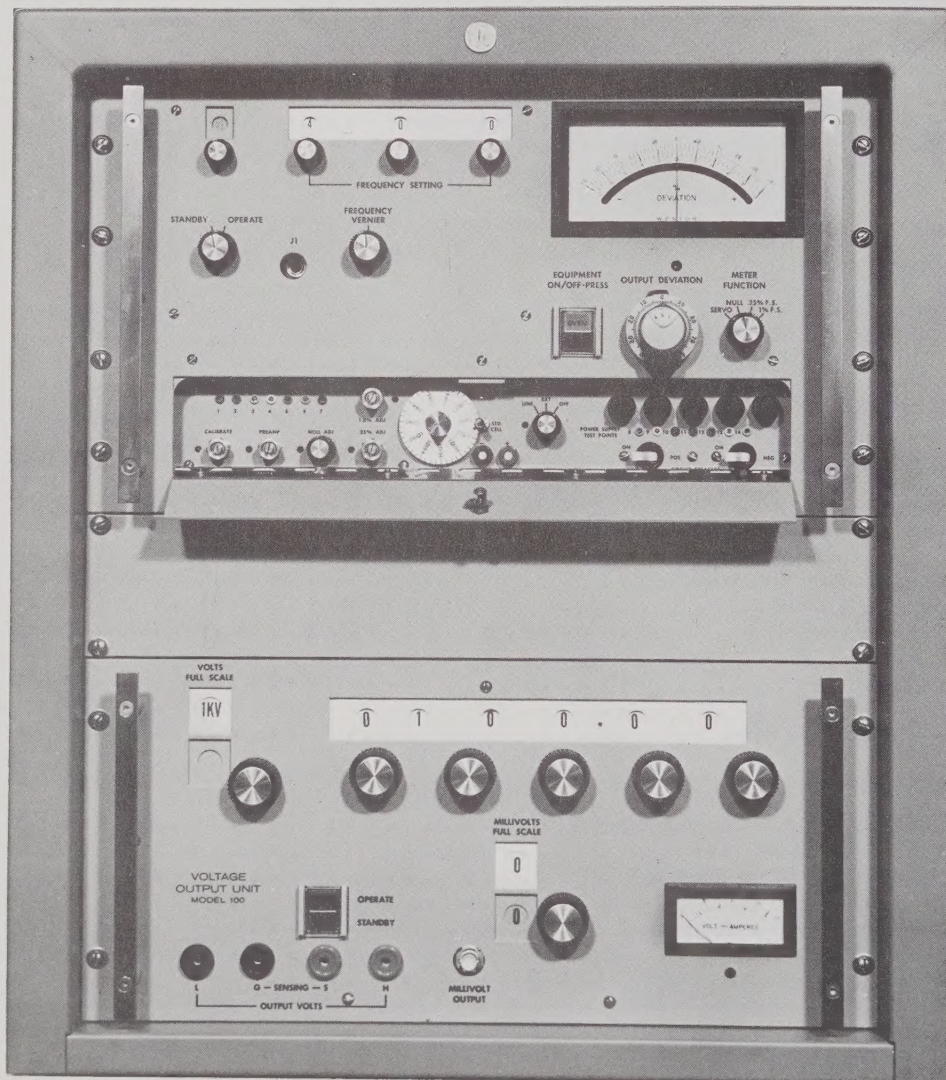


Figure 1. AC Voltage Standard showing Test Points Located in Compartment on Front Panel of Control Unit.

GENERAL DESCRIPTION

PURPOSE

Application flexibility is the salient design characteristic of the Model 100 System; each major circuit is mounted on a standard 19-inch relay rack panel. Starting with either the basic Voltage or Current Standard, accessory panels can be added as future requirements arise without replacing the original equipment or obsoleting any of the functions. Since each basic standard has its own supply, they can be interconnected and an accessory panel added to the Current Standard to permit AC wattmeter calibration at various phase angles.

The Model 100 System is particularly suited for the calibration and standardization of precision meters and digital voltmeters and includes a feature for reading the % error of a meter directly, thus eliminating the usual error calculations.

Other uses include gyro navigation system calibration, computer programming, and resolver, capacitor, inductor, amplifier, transformer and filter testing.

DESCRIPTION

The Model 100 System is a completely solid state, ultra precise sine wave source of emf from 1 millivolt to 1000 volts at 50 Hz to 10 kHz and current from 1 milliampere to 50 amperes at 50 Hz to 3 kHz. Output frequency is continuously variable and is set by three digital reading dials from 50 to 1000 Hz; above 1 kHz a 4th dial (multiplier) is also used. Output emf or current is selected by five dials and a range selector; the decimal point is automatically set by the range selector.

Major ranges are all direct reading; output emf or current corresponds to digital readout of the output selector dials when % deviation meter is set to 0. For maximum convenience in downscale calibration and to supply full rated burden under all conditions, intermediate ranges can be selected using a multiplier that automatically appears under the full scale range selected.

The standardizing circuits employ a stable, aged zener diode mounted in a temperature controlled oven at 55°C as a source of DC voltage for a working reference, plus a thermally lagged, certified laboratory type standard cell as a basic reference and self-checking feature having a long term (one year) stability of .005%. The standard cell, equipment calibration controls and test points are available through the front panel of each Control Unit by opening a hinged cover plate as shown in Figure 1.

For rapid calibration of meters, the outputs can be raised or lowered from the nominal value indicated on the dials and the % error read directly from an accurate TBS panel meter. Two ranges are available, one having a resolution of .01% per scale division and the other .05% per division.

A proprietary arrangement of mechanical interlocks protects both the operator and device being tested or calibrated. All output dials must be turned fully counterclockwise before the range switch can be changed. The frequency dials are interlocked with the frequency range multiplier dial and the standby-operate switch to prevent frequency and range changes while the equipment is in operation. Warning lights show standby and operate conditions and an amber light indicates cycling of the zener reference oven temperature. Output terminals are recessed.

All semiconductor amplifiers and circuits compatible with printed wiring technique are mounted on plug-in boards for convenient test and maintenance. Large heat sinks are provided for convection cooling of the power transistors and rectifiers.

Three direct reading frequency dials with an overlapping vernier control permit continuous adjustment of the frequency of the voltage controlled oscillator as shown in block diagram, Figure 2. With the standby-operate switch in the operate position, the output of the oscillator is applied to the input of the power amplifier, energizing the potential transformer network. This network adjusts the output voltage to a value near the dial reading. The output of the transformers is sensed with the range attenuator and applied to the range amplifier. The output dials control the range amplifier over a 10:1 range, thus maintaining a fixed voltage on the input of the operational rectifier for the output voltage indicated by the dials on the AC Voltage Standard Output Unit. An operational rectifier then converts the signal to a DC current for accurate comparison to a current from the zener working reference. A high gain photo-chopper stabilized amplifier, with associated RC compensation networks, completes the loop and is used to provide a high servo loop gain and stabilize the control system. The DC output of the zener is compared to the standard cell by a photo-chopper stabilized DC amplifier, and any difference is indicated on the TBS front panel meter; the operator always knows from observation that the output value is correct as set, regardless of any excessive line voltage fluctuations, extraordinary burdens or unusual circuit changes.

In the standby position of the control switch, the output of the oscillator is connected directly to the input of the operational rectifier, and the output circuits are not energized. This permits the circuits to maintain temperature, thus eliminating warm-up time when operation is on an intermittent basis. The standby/operate warning light is near the output terminals to remind the operator to switch to standby condition before changing leads.

As shown in block diagram of Figure 3, the major difference between the Model 100 Voltage Standard and the Model 100 Current Standard is in their output modules. Operation of the servo loop control is the same with the voltage drop across a precision oil immersed shunt being fed back to the operational rectifier for standardization in the Current Standard Control Unit.

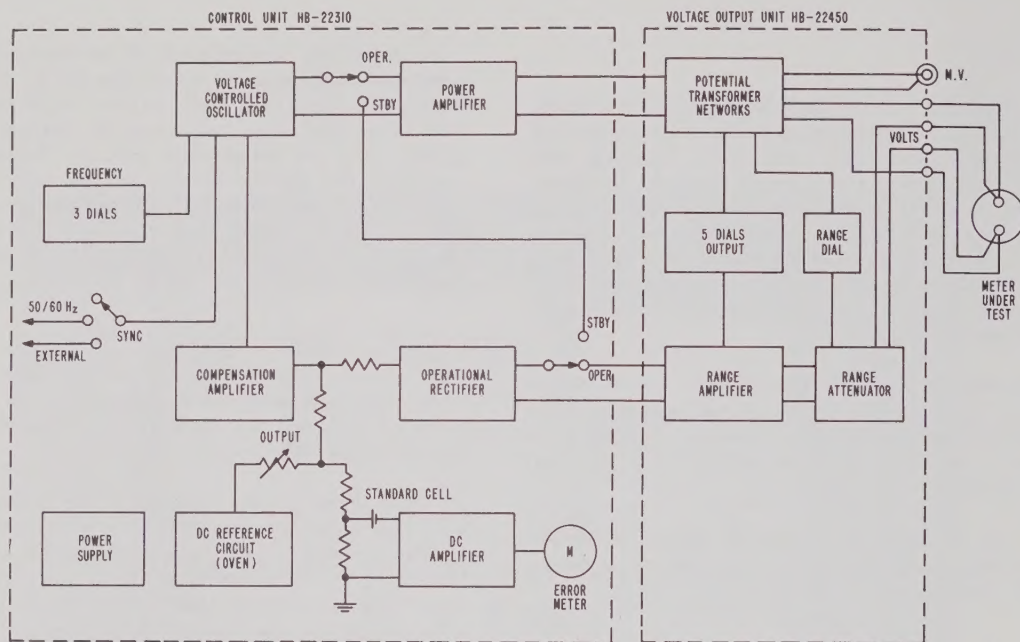


Figure 2. Block Diagram of Voltage Standard.

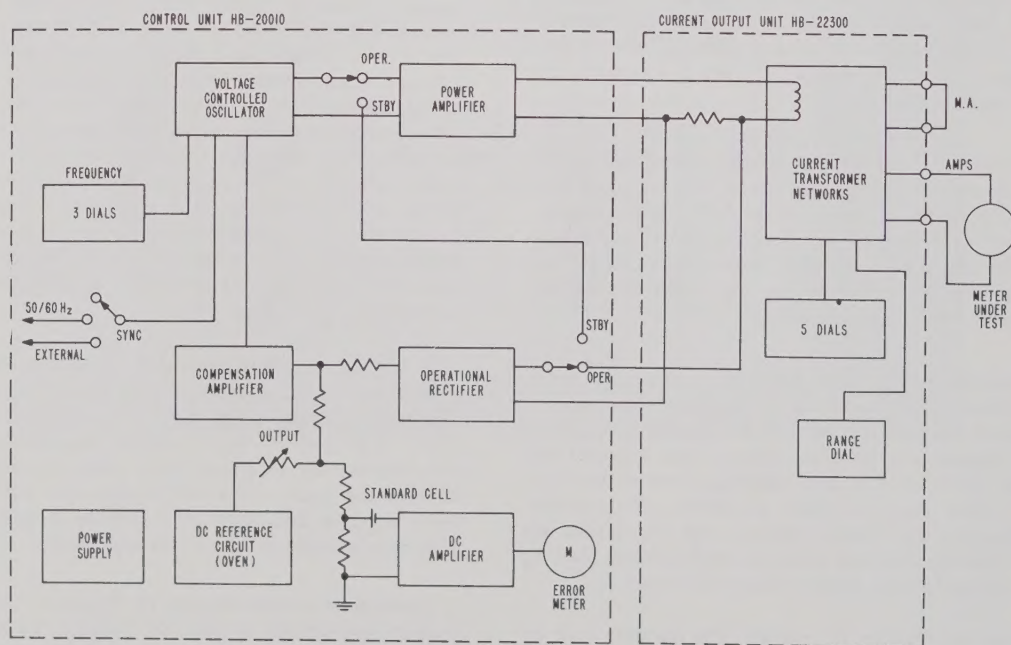


Figure 3. Block Diagram of Current Standard.

For wattmeter calibration, the oscillator output of the Model 100 Voltage Standard is connected to the external sync terminals of the Current Standard and the oscillators electrically locked together by adjusting the frequency dials of the Current Standard. Electrical lock can be maintained over plus and minus 60 degrees of phase angle relationship. An accessory panel, HB-22690, is available for the Current Standard which includes a 90° phase shifter at 50, 60, 400, 1000 and 2000 Hz to permit the calibration of VAR meters and a high frequency shunt for 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10, 20, and 50 amperes at 0.1 volt output. An external phase meter or oscilloscope can be connected to observe phase relationship between the output voltage and current.

A thermally lagged, built in standard cell (.005% long term stability) is provided as a reference check for the zener DC working standard. A change in either one of the standards is indicated by a change of dial reading of the ten turn OUTPUT DEVIATION control.

The AC Voltage Standard employs 4-terminal sensing which enables the current to pass to the device being tested on one pair of leads and the voltage drop to be measured

by another pair. This allows high burdens to be connected without additional error due to lead losses; it eliminates the effect of load changes on amplitude accuracy. The Current Standard has two terminal output from high quality current transformers which are compensated for load changes. Panel meters indicate the approximate output power up to 20 VA and are used to prevent overloading the standards.

As an optional feature an additional switch section can be added to the range and decade dials switches and wired to connectors at the rear of the chassis. This provides a 10-line code for digital print out of dial setting.

Physically the Model 100 System is designed for RETMA Standard 19-inch relay rack mounting. Each equipment is mounted in a steel and aluminum bench type cabinet 22-1/4" wide, 26-1/2" high and 19-1/2" deep. The control units have 19" by 10-1/2" panels and require a 16-1/2" depth behind the panel. The output units have 19" x 8-3/4" panels and are 12" deep. Space for cables and the thermal case for the standard cell at the rear of the output units requires a 16-1/2" clearance behind the panel for the mounting of these units. A 3-1/2" panel space is provided for accessories.

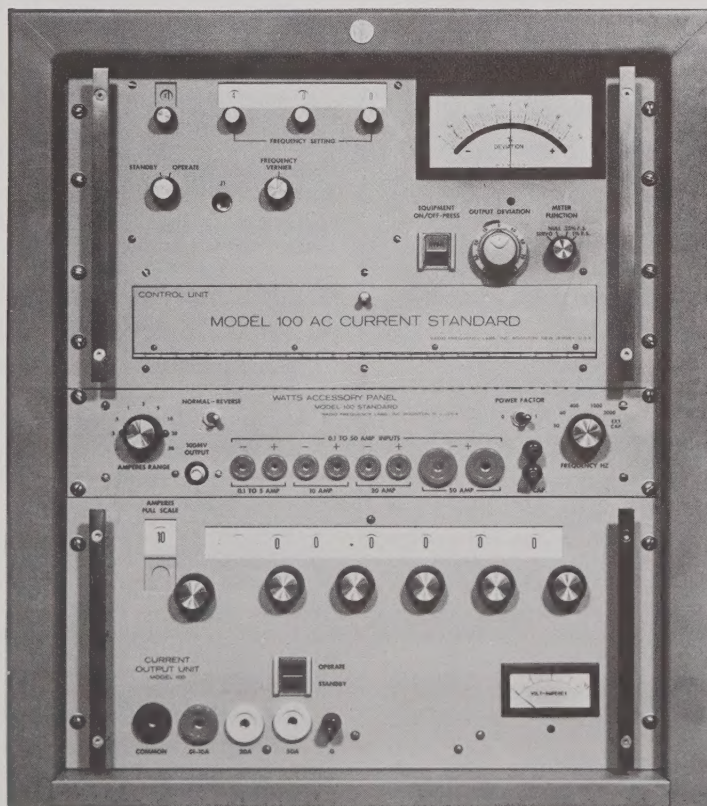


Figure 4. AC Current Standard with Watts Accessory Panel.

TABLE I.
Technical Data Summary

Model 100 AC Voltage Standard

Output Ranges: 1 to 10, 2-20, 5-50, 10-100, 20-200, 50-500, 100-1K, 200-2K, 500-5K & 1K-10K MV; 1 to 10, 2-20, 5-50, 10-100, 20-200, 50-500 & 100-1000 V.

Output Power Capability at Rated Accuracy:

10 MV to 500 MV 10K load
1 K MV to 10 K MV 50K load
10 V to 1000 V 20 VA to 5 kHz, 10 VA to 10 kHz

Output Resolution: 5-decade readout w/moving dec. pt.

Load Indication: By panel meter to 20 VA.

Output Frequencies: Continuously variable from 50 Hz to 10 kHz with digital readout. 3-decade resolution with vernier. Accuracy $\pm 1\%$.

Frequency Stability: $\pm 0.25\%$ and oscillator also locks to line. Wattmeter calibration available when used with Current Standard.

Total Harmonic Distortion: $\pm 0.035\%$ (50 Hz to 10 kHz)

Loading Effects: Negligible on amplitude accuracy and distortion. 4-terminal sensing from 1 to 1000 volts.

Overload Protection: Circuit breakers and fuses.

Input Power: 115/230 volts, 50/60 Hz, 285 watts.

Printer Output: Optional 10-line code for digital print-out of dial setting.

Internal Reference Standards: Precision zener plus a standard cell ($\pm 0.005\%$ long term stability) for self-checking.

* Accuracy of Output at $25^\circ\text{C} \pm 5^\circ\text{C}$ (one year)

$\pm 0.038\% + 1 \mu\text{V}$ from 50 Hz to 2 kHz
 $\pm 0.064\% + 1 \mu\text{V}$ from 2 kHz to 5 kHz
 $\pm 0.128\% + 1 \mu\text{V}$ from 5 kHz to 10 kHz

Model 100 AC Current Standard

Output Ranges	Burden (Max.)	Frequency
0.001 to 0.01 A	10K ohms	50-100 Hz
0.002 to 0.02	4K ohms	50-100
0.005 to 0.05	1K ohms	50-100
0.01 to 0.1	5 VA	50-100
0.02 to 0.2	5	50-100
0.05 to 0.5	10	50-3000
0.1 to 1.0	10	50-3000
0.2 to 2.0	10	50-1000
0.5 to 5.0	10	50-400
1.0 to 10.0	10	50-400
2.0 to 20.0	10	50-400
5.0 to 50.0	10	50-400

Output Resolution: 5-decade readout w/moving dec. pt.

Load Indication: By panel meter to 20 VA.

Output Frequencies: Continuously variable from 50 Hz to 3 kHz with digital readout. 3-decade resolution with vernier. Accuracy $\pm 1\%$.

Frequency Stability:

$\pm 0.25\%$ and oscillator also locks to line. Wattmeter calibration available when used with Voltage Standard.

Total Harmonic Distortion:

$\pm 0.035\%$ from 50 Hz to 3 kHz.

Input Power: Same as Voltage Standard.

Printer Output: Same as Voltage Standard.

Internal Reference Standard: Precision zener plus a standard cell ($\pm 0.005\%$ stability) for self-check.

* Accuracy of Output at $25^\circ\text{C} \pm 5^\circ\text{C}$ (one year)

$\pm 0.056\% + 2 \mu\text{A}$

*** Derivation of Rated Accuracy**

Limits of error of calibration:

NBS certified accuracy of sat. std. cells $\pm 0.001\%$
Model 1000 guarded pot. (to 1.5 volts) $\pm 0.001\%$
Model 400 AC-DC transfer standard $\pm 0.01\%$
RFL guarded volt-ratio box (used on outputs above 1.5 V) $\pm 0.005\%$
Total cal. uncertainty above 1.5 V $\pm 0.017\%$

4-terminal shunts (replace volt-ratio box for current calibration) $\pm 0.005\%$

Systematic errors - Voltage Standard:

Possible ratio network & oper. amp. errors (downscale) 50 Hz-2 kHz $\pm 0.01\% + 1 \mu\text{V}$
2 kHz-5 kHz $\pm 0.03\% + 1 \mu\text{V}$
5-10 kHz $\pm 0.06\% + 1 \mu\text{V}$

Systematic errors - Current Standard:

Possible ratio network (downscale & loading errors) 50 Hz-3 kHz $\pm 0.03\% + 1 \mu\text{V}$

Long term (one year) stability - Voltage Standard:

Internal standard cell $\pm 0.005\%$
Maximum possible deviation of three resistance ratios $\pm 0.006\%$
Total instability $\pm 0.011\%$

Long term (one year) stability - Current Standard:

Internal standard cell $\pm 0.005\%$
Maximum possible deviation of two resistance ratios $\pm 0.004\%$
Total instability $\pm 0.009\%$

INSTALLATION

GENERAL

The cabinets of the Model 100 System are designed for bench mounting. About 12 to 15 inches should be allowed in front of the cabinets for the placement of instruments and equipment under calibration. Digital voltmeters will require bench space at the sides. As only convection type cooling is used a minimum of 6 inches of clearance should be provided at the rear of the cabinet for air circulation. Clean air conditioned rooms are the preferred working environment for the Model 100 System and the equipment being standardized or calibrated.

Support rails must be used if installation in a standard 19" rack is planned.

LINE SOURCE

The equipment is designed to operate from 115 or 230 volts, 50 or 60 Hz. For 115 volt sources use the 3 prong line cord plug supplied and check that the 115-230V switch on the rear of the control unit is in the 115-volt position. For 230-volt sources replace the line cord plug with proper 230-volt plug and place the 115-230V switch to the 230V position. A power line should be selected that is not also used for motors and welding equipment.

WATTS ACCESSORY PANEL CONNECTIONS

When the Watts Accessory Panel (HB-22690) is supplied and the Voltage Standard is to be locked to the Current Standard, this panel is mounted in the center panel position of the Current Standard as shown in Figure 4. A cable is plugged from the 10V jack J102 at the rear of the Voltage Standard Control Unit to the 10V jack J1 at the back of the Watts Accessory Panel. From the SYNC jack J2 of the Panel, a short cable is run to the SYNC jack J101 at the rear of the Current Standard Control Unit.

PRELIMINARY

A. Standardization

Open hinged panel on lower front of Control Unit (see Figure 1) and make sure the STD CELL dial is set to the value given on the certification sheet supplied. Terminals are provided for conveniently checking the internal cell against an external standard if desired. Also check that SYNC knob to right of standard cell dial is set to OFF for these preliminary tests.

Before operating set STANDBY-OPERATE switch to STANDBY and set frequency to 100 Hz. On the Voltage Standard, check that the jumper terminals are in place on the output receptacles connecting the sense circuit to the power circuit, the VOLTS FULL SCALE switch is set for 10 volts and the output dials are set low at 1.0 volt. On the Current Standard, connect a 10 ampere full scale AC ammeter to the COMMON and 10A receptacles, set the AMPERES FULL SCALE to 10A and output dials to zero.

Plug the power cable into the line receptacle. Press the EQUIPMENT ON-OFF button to energize the unit. The button should light. Set the METER FUNCTION switch to SERVO. In this position the meter monitors the output of the compensation amplifier. An indication in the range of $\pm .15\%$ deviation on the upper scale indicates that the servo loops are in control. Allow 15 minutes for the oven to stabilize as indicated by the cycling of the OVEN lamp. Within this time the meter should be in the range $\pm .05\%$ deviation on the top scale for a frequency setting of 50-1000 Hz.

Check the standard cell amplifier zero reference by switching the METER FUNCTION switch to NULL. If meter does not read zero (center scale) set to zero with the NULL ADJUST control under the front panel cover plate.

Compare the standard cell and zener reference source by switching the METER FUNCTION switch to .25% F.S. Check that the OUTPUT DEVIATION control is positioned as given in the calibration data supplied. The meter should read within $\pm .005\%$ of zero.

B. Output Check

Check for output on the Voltage Standard by connecting a 10V full scale AC voltmeter to the output terminals and observing 1.0 volt output when the STANDBY-OPERATE switch is turned to OPERATE. Turn output dials up to 10.000 and observe 10 volts out. To change ranges set STANDBY-OPERATE switch in STANDBY, set output dials to lowest value (1.0 in this case) and turn VOLTS FULL SCALE to desired range. Check that voltmeter under test is on proper range before turning to OPERATE. No power is applied to the Output Unit until the STANDBY-OPERATE switch is placed in OPERATE.

Check for output on the Current Standard by connecting a 10 ampere full scale AC ammeter to the COMMON and 10A output terminals. Turn STANDBY-OPERATE control to OPERATE and increase the output dial readings. Observe 0 to 10 amperes output on ammeter. To change ranges turn STANDBY-OPERATE switch to STANDBY, set all output dials to zero and turn AMPS FULL SCALE switch to desired range. Check that ammeter under test is on proper range before turning to OPERATE. No power is applied to the Output Unit until the STANDBY-OPERATE switch is in OPERATE position.

NOTE

The current transformers of the Current Output Unit must be kept shorted through an ammeter, external link or cable if the dials are moved off zero. Otherwise, unpleasant potentials can exist at these terminals.

This completes preliminary tests upon installation. Read Section on Operation before further use.

OPERATION

GENERAL

1. Before turning ON the equipment turn STANDBY-OPERATE switch to STANDBY. (Equipment will not start up with switch in OPERATE position) Allow 15 minutes for the oven to stabilize and bring the zener reference standard to operating temperature when equipment is first energized.

2. Press the EQUIPMENT ON-OFF switch button and note that button lights to indicate power on.

3. Place the METER FUNCTION switch in SERVO position and observe by the panel meter that the servo loop assumes control within 1 to 3 minutes. A stable meter reading between $\pm 10\%$ and $\pm 10\%$ on the top scale indicates normal operation at no load and frequencies below 1000 Hz. Meter readings greater than $\pm 20\%$ deviation indicate malfunction.

4. Set output FREQUENCY SETTING dials for the desired frequency.

5. Compare the standard cell to the zener standard by turning METER FUNCTION switch to NULL and adjusting NULL ADJUST control for meter zero then, turning to $\pm 25\%$ F.S., set OUTPUT DEVIATION control for meter zero. Note reading of control should be within two divisions of value given on certificate. This is your assurance that output of either reference standard has not changed.

The step-by-step procedure that follows for calibrating AC voltmeters, millivoltmeters and ammeters includes use of the OUTPUT DEVIATION control and the % DEVIATION meter to eliminate error calculation and, in most cases, is the most rapid method of calibrating downscale points. However, when using either Standard as a supply source or when calibrating meters at full scale, the OUTPUT DEVIATION control is usually left at the zero reference setting as given in the calibration certificate (% DEVIATION meter at zero). Either procedure is at user's option.

CALIBRATION OF AC VOLTMETERS

To calibrate high burden voltmeters use four terminal sensing at the terminals of the voltmeter under test. From the high side of the voltmeter under test connect cables to receptacles H and S. From the low terminal of voltmeter connect cables to L and G.

For high impedance voltmeters, receptacles H and S are shorted at the panel with a plug assembly. Likewise, receptacles L and G are shorted together. The low side of the instrument under test is connected to L-G and the high side is connected to H-S terminals. (The G terminal is connected to ground inside the equipment.)

1. Check voltmeter connections. If voltmeter is AC operated use adapter in voltmeter line cord to break its ground connection, thus preventing ground loops.

2. Check that output dials read zero and set VOLTS FULL SCALE to desired range.

3. Turn STANDBY-OPERATE switch to OPERATE.

4. Turn output dials to the desired full scale or index value of the voltmeter being calibrated.

5. Turn the OUTPUT DEVIATION control until the voltmeter reads the selected value.

6. Read the % error of the voltmeter directly on the front panel meter.

7. Turn OUTPUT DEVIATION control back to 0% deviation and return the output dials to full counterclockwise position (minimum output).

8. Return the STANDBY-OPERATE switch to STANDBY.

9. Disconnect voltmeter.

CALIBRATION OF AC MILLIVOLTMETERS

Standardization of the millivolt function requires that the SENSING terminals be shorted to the OUTPUT VOLTS terminals; that is, receptacle L is shorted to G and S is shorted to H with a plug assembly.

1. Connect millivoltmeter using shielded cable and BNC connectors. If millivoltmeter is AC operated use adapter in millivoltmeter line cord to break its ground connection, preventing ground loops.

2. Check that output dials read zero and set MILLIVOLTS FULL SCALE switch to range desired.

3. Turn STANDBY-OPERATE switch to OPERATE.

4. Turn output dials to the desired full scale or index value of the millivoltmeter being calibrated.

5. Turn the OUTPUT DEVIATION control until the millivoltmeter reads full scale or to the selected value.

6. Read the % error of the millivoltmeter directly on the front panel meter.

7. Turn OUTPUT DEVIATION control back to 0% deviation and return the output dials to full counterclockwise positions (minimum output).

8. Return the STANDBY-OPERATE switch to STANDBY.

9. Disconnect millivoltmeter.

CALIBRATION OF AC AMMETERS

1. Connect ammeter between COMMON and $\pm 0.1-10A$ terminal if ammeter range is below 10A and COMMON to 20A or to 50A if range is above 10A.

2. Check that output dials read zero and set AMPERES FULL SCALE switch to range desired.

3. Turn STANDBY-OPERATE switch to OPERATE.

4. Turn output dials to the desired scale or index value of the ammeter being calibrated.

5. Turn the OUTPUT DEVIATION control until the ammeter reads the selected value.

6. Read the % error of the ammeter directly on the front panel meter.

7. Turn OUTPUT DEVIATION control back to 0% deviation and return the output dials to full counterclockwise position (zero).

8. Return the STANDBY-OPERATE switch to STANDBY.

9. Disconnect the ammeter.

CALIBRATION OF WATTMETERS

Calibration of wattmeters requires both a Voltage and Current Standard with a cable connection between 10V jack J102 of the Voltage Standard and SYNC jack J101 of the Current Standard. The output of the Current Standard can be electrically phase locked to the Voltage Standard over $\pm 60^\circ$ phase variation. An external high frequency

shunt and phase meter are required to adjust phase. An oscilloscope may be used in lieu of a phase meter as shown in Figure 5 for tests at zero phase angle.

The Watts Accessory Panel (HB-22690) consists of a 90° phase shifting network permitting electrical lock at any phase angle and a multi-range high frequency shunt. Front panel connections for use of this accessory are shown in Figure 6. The SYNC switch of the voltage standard is set in the OFF position and the SYNC switch of the current standard is set in the EXT position. (Each switch is located in a compartment accessible through a hinged cover on the front panel of each Control Unit.) Turn the FREQUENCY SETTING dials to the same frequency. If calibrations are to be made at line frequency, set frequency dials at this frequency and the Voltage Standard SYNC switch to LINE.

Operate the Voltage Standard to apply rated voltage to the wattmeter voltage terminals and the Current Standard to obtain rated current in the current side of the wattmeter. Adjust FREQUENCY VERNIER and last FREQUENCY SETTING dial of the Current Standard to electrically lock the outputs of the two units together and control the phase angle between the voltage and current to the desired value as observed on the oscilloscope or phase meter, whichever is used. Phase meters used for this application should be stable at zero phase angle (many phase meters are not usable at zero phase angle). A recommended type is the Model 405 with Type A102 Pre-Amplifier of the Ad-Yu Electronics Lab.

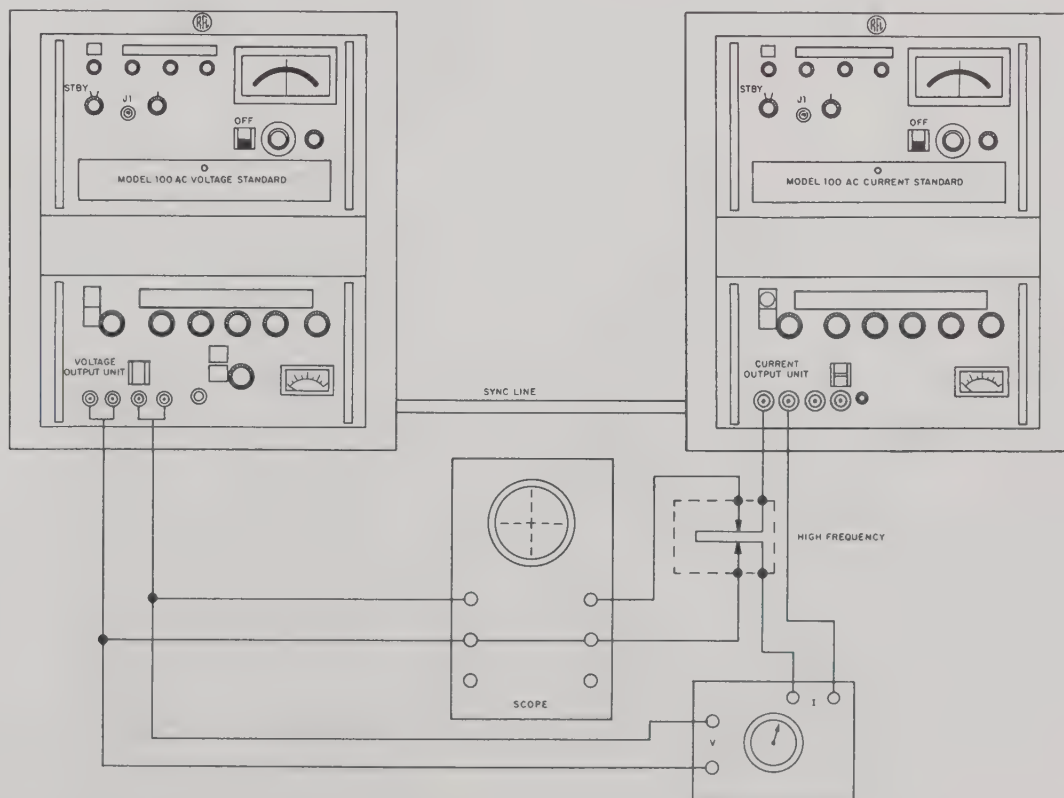


Figure 5. Connection for Wattmeter Calibration.

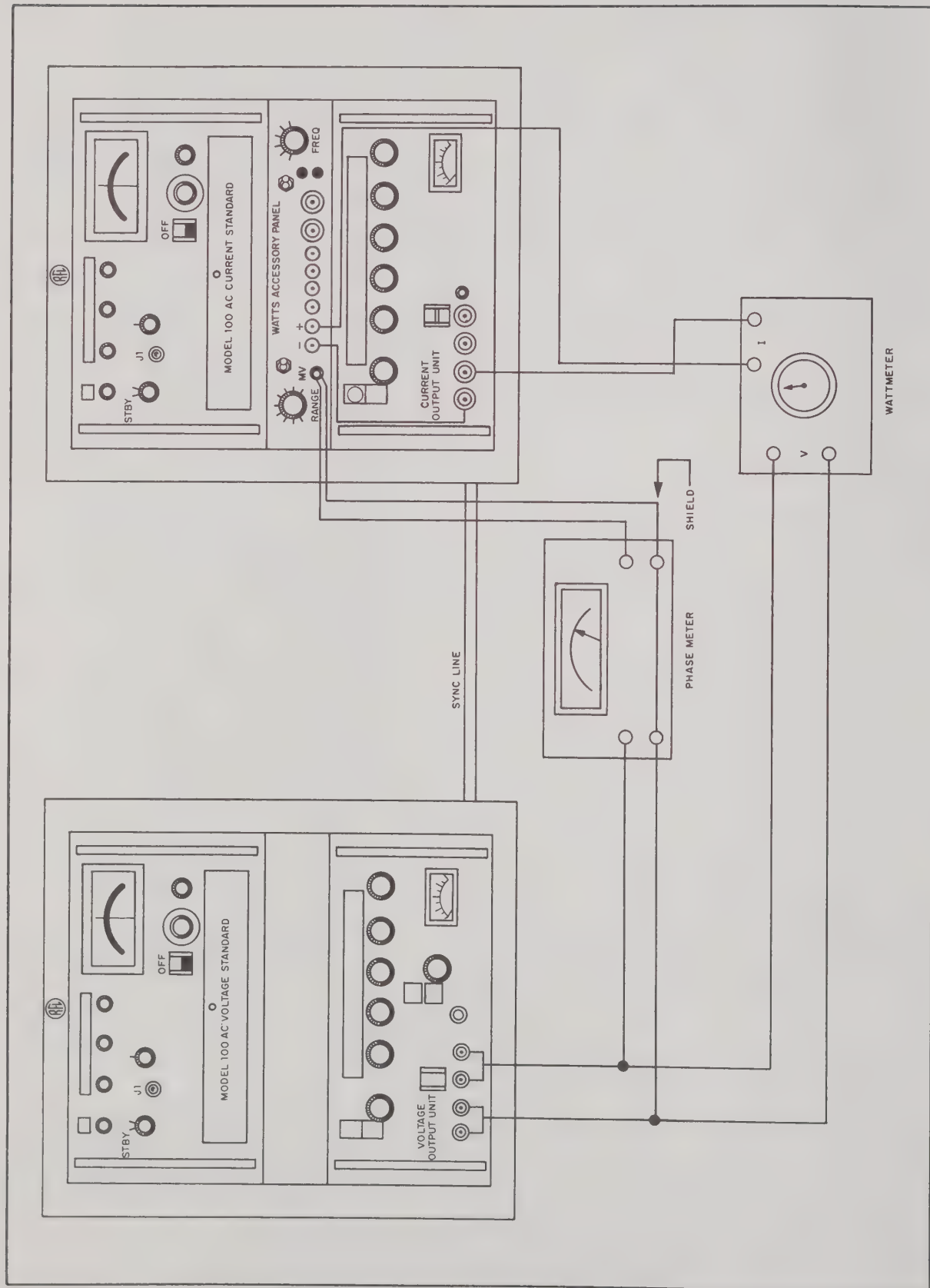


Figure 6. Connection for Wattmeter Calibration with Watts Accessory Panel.

THEORY OF OPERATION

GENERAL

The over-all block diagrams of the Voltage and Current Standards are shown in Figures 2 and 3. Both standards are essentially the same in operating principle and consist of a DC reference standard, a high gain DC photo-chopper amplifier, a voltage controlled oscillator, a power-amplifier, output impedance matching networks, and an operational rectifier to convert the AC back to DC to compare against the reference standard. The Control Units of the Voltage and Current Standards are identical except for value of two resistors and mechanical stops on the FREQUENCY SETTING dials, as these dials are stopped at 10 kHz in the Voltage Standard and at 3 kHz in the Current Standard.

OSCILLATOR CONTROL UNIT

This unit is a low distortion, voltage controlled oscillator. The schematic diagram is given in Figure 7. Details of the oscillator amplifier (HB-20015) are shown in Figure 8.

The oscillator uses a Wein bridge network with frequency control by changing resistors. The resistance arms of the bridge are varied by decade switches to give a direct read out of frequency. Frequency ranges are changed by switching capacitors. Capacitors C14 and C15 are used for the 50 to 100 Hz range, C16 and C17 for the 100 to 1000 Hz range and C18 and C19 for the 1000 to 10,000 Hz range.

Amplifier A1 is a direct-coupled high gain amplifier with a gain of 1.0 and used for matching the transistor circuitry to the variable impedances of the Wein bridge. The feedback resistance is maintained equal to the frequency controlling resistances of the Wein bridge by identical switch decks and resistors as are used in the Wein bridge. Amplifier A2 is a direct coupled high gain amplifier with feedback resistors arranged for a gain of 3 plus or minus 3%. The variable gain feature is controlled by a field effect transistor (FET 101) in the feedback network. This FET is mounted in the temperature controlled oven. The output of A2 energizes the bridge. Amplifier A3 and its output rectifier supply a DC control voltage to the field effect transistor gate to establish amplitude control over the oscillations. The gain control R31 and feedback controls R45, R46, and R47 permit centering of the operating points of the voltage applied to the field effect transistor for 10 volts AC output of the oscillator. Amplifier A1 consists of transistors Q1 to Q6; amplifier A2 consists of Q7 to Q12; amplifier A3 consists of a phase splitting amplifier Q13. Diodes CR5 and CR6 make up a full wave rectifier, the output of which is filtered and applied to the gate of the field effect transistor. Provision is made with control R14 to insert second harmonics from the rectifiers into the input of amplifier A2, so cancelling out most of the second harmonic distortion of the oscillator.

Electrical phase lock to an external frequency is accomplished by tuning the oscillator to this external frequency

and inserting a like frequency current into the input of amplifier A2 via 510K resistor R44. A jack (J1) is provided on the front panel to insert an external oscillator of $3.3 \pm 3\%$ volts output. The external oscillator feature is used to trouble shoot the servo circuit. Because changing the frequency range switch or the frequency dial switches causes voltage transients in the oscillator output, the STANDBY-OPERATE switch is mechanically interlocked with the frequency range and decade dials so that this switch must be in STANDBY before the frequency range or dial switches can be changed.

POWER AMPLIFIERS

The power amplifiers of the Voltage Standard and the Current Standard are identical except for the feedback networks. Figure 9 shows a schematic diagram of the power amplifiers. The circuitry is packaged in two parts. The small high gain transistors are packaged on a plug-in printed circuit and the power transistors are mounted on heat sinks. A direct coupled amplifier configuration is used with a unity gain bandwidth of 1 mHz. Two feedback networks are used to reduce the normal open loop gain of 3000 to a gain of 2. The first loop encompasses the amplifier and reduces its gain to 20. The second loop of the current amplifier feeds back from the shunt, thus making a constant current output network to feed the current transformers while the second loop of the voltage amplifier feeds back from the transformer creating a constant voltage output to feed the output transformers. The transistors Q1, Q2, Q3, Q4, Q5, Q6 and associated parts provide the direct coupled voltage gain of the amplifier. Transistors Q8, Q9, Q10, Q11, Q12, Q13, Q14 and associated parts make up a power amplifier of unity gain.

All the components that differ between the power and current power amplifiers are associated with the frequency compensation of the amplifiers to obtain feedback stability. These component changes are listed in Figure 9.

CHOPPER-STABILIZED AMPLIFIERS

The same basic chopper stabilized amplifier is used for the operational rectifier, the compensation amplifier and the standard cell amplifier. The frequency compensating components and input resistors vary between the application. Otherwise the amplifiers are identical. Figure 10 shows a schematic diagram of the amplifier with the variable components tabulated for the specific application. A photo chopper modulator, operating at 60 Hz, is used at the input of the chopper amplifier. The gain of the chopper amplifier from DC volts in to DC volts out is approximately 1000. The gain of the AC coupled amplifier is nominally 20,000 with a unity gain bandwidth of 1 mHz, giving an over-all DC gain of 20 million. Transistors Q9, Q10, Q11, Q12, Q13, Q14, and Q15, and the photo chopper modulator make up the stabilizing chopper-amplifier. Transistors Q1, Q2, Q3, Q4, Q5, Q6, Q7, and Q8 form the AC amplifier. The output stage is capable of supplying 10 volts AC across 1000 ohms. The zero offset voltage is adjusted by means of potentiometer R29.

RANGE AMPLIFIER

The range amplifier works in conjunction with a precision 5-dial ratio transformer to accurately vary the gain of the ranging circuits between 1 and 10 that is required to deliver 10 volts output to the operational rectifier for a 1 to 10 voltage change at the equipment output terminals. As shown in Figure 11, the amplifier consists of two sections with a compensation attenuator between the two sections. The compensation attenuator maintains a constant loop gain in the feedback network as the 1st and 2nd dials are varied. Each section of the amplifier uses internal degenerative feedback to stabilize the loop gain. An overall loop gain of 60db is maintained around the feedback network. Resistor R3 is driven by the ratio transformer output. The ratio transformers (see Figure 12) are driven through the RF frequency compensating network consisting of R47, C10 and C11. The input resistor (R1) is driven by the input attenuator across the sensing terminals. The major part of the amplifier gain is obtained from transistor Q1, Q2, Q3, Q4, and Q5. Transistors Q6, Q7, and Q8 provide the power gain necessary to drive the compensation attenuator. The output amplifier consisting of Q9, Q10, Q11, Q12, Q13, and Q14, and working in conjunction with the compensation attenuator provide a 10:1 gain change to maintain a constant loop gain.

OUTPUT UNIT (VOLTAGE STANDARD)

This unit consists of a high voltage ratio transformer network for matching the load to the power amplifier, a resistive input attenuator, a range amplifier with ratio transformers for scaling a 10:1 ratio of voltage at the sensing terminals to a fixed output voltage to operate the operational rectifier. With reference to Figure 12, the output of the power amplifier is transformed up to 100 volts in steps of 10 volts by ratio transformer T-401. Dial 1 selects 0 to 100 volts in 10 volt steps. Dial 2 selects 0-10 volts in 1 volt steps and dial 3 selects 0-1 volt in 0.1 volt steps from transformer T405. The range switch selects the full scale range of output voltage from the transformer T402. Millivolt outputs are obtained from transformer T406. Transformer T407 senses the current in the primary of transformer T401 and feeds a voltage back to the input of the power amplifier to maintain a constant output voltage. Potentiometer R402 adjusts the amount of voltage fed back to the input of the power amplifier. The 2.0 ohm resistor R401 provides a DC voltage drop which stabilizes the power amplifier for DC drift. Resistor R401 is shunted by 10,000 uF capacitors C401 and C402 to by-pass the alternating current. The power delivered to the output transformer and load is indicated by meter M401. The transistor Q401 and associated components are arranged to measure the in phase component of current into the 100-volt tap of the range transformer T402. Resistor R406 sets the full scale calibration of meter M401 for 20 volt amperes in the load.

The range attenuator senses the output voltage of the transformer network and calibrates each range. Potentiometers R426, R432, R436, R438, R440, R442, R444, and R445 calibrate the full scale ranges. Resistor R403 is a factory value of resistance of approximately 860 ohms that is adjusted in test to compensate for variations in tolerance of resistors in the operational amplifier and the

range amplifier so as to center the full scale calibration controls. The range amplifier and transformer ratio networks consisting of transformers T403 and T404 accurately change gain inversely with dial position so that the output of the range amplifier is always 10.0 volts as required for operation of the operational rectifier.

OUTPUT UNIT (CURRENT STANDARD)

This unit consists of a precision current ratio transformer network, a precision shunt and calibration controls for standardizing the output currents of the AC Current Standard. With reference to Figure 13, the output of the power amplifier is applied through 10,000 μ F capacitors C1 and C2 to the current ratio transformer network consisting of transformers T304, T303, T302, T301 and T306. In series with this transformer network is the precision 2.00 ohm shunt R308. The current through R308 is maintained at 2.0 amperes (the voltage drop at 4.0 volts) by the Control Unit. The input resistor of the operational rectifier of the Control Unit is 3880 ohms with the calibration network in the Output Unit increasing this to 4000 ohms, as compared to a total of 10,000 ohms input resistance used in the AC Voltage Standard.

The primary of T305 is connected across the output current transformer to obtain a signal proportional to the burden placed across the output terminals. One secondary adds a regenerative signal to the feedback path from the shunt to the input of the power amplifier. The amount of this signal is controlled by R302 which is adjusted for a constant current output on a short time basis (1 cycle of signal). The second secondary of T305 places regenerative signal in series with the shunt and applies a burden correction to the operational amplifier and compensation amplifier which requires about 4 seconds to stabilize. One set of calibration controls consisting of R302 and associated parts is used for current output transformer T301 (0.1 to 50A) and another set consisting of R303 and R304 is used when the transformer T306 (.01 to .05A) is connected. Potentiometer R303 adjusts the long term (3 second) correction for burden change. Potentiometer R304 adjusts the system calibration when output transformer T306 (.01 to .05A) is used. The factory value of R315 is used to set the output to the rectifier at 3.880 volts on the 2.0A range.

Resistors R311, R312, R313, R314 and factory values of resistance are switched across the shunt by a section of the 1st dial to compensate coupling errors in the first four positions of this dial.

Open circuit protection of the output current transformer and limitation of the open circuit output voltage are provided by zener diodes CR305 to CR308 connected across taps on the output current transformer.

CONTROL UNITS

These units consist of the basic zener and standard cell standards, the standard cell comparison amplifier and associated networks, the voltage controlled oscillator and servo circuits, and a power amplifier and power supply. Voltage and Current units are identical except for frequency range, input resistor to operational rectifier and power amplifiers. See Figures 14 and 15.

The basic zener standard is CR101. This is an aged and pre-tested unit mounted in a proportional temperature controlled oven at 55°C. Zener CR102 pre-regulates the voltage applied to CR101. The -9V zener reference voltage is divided down to -8,000 volts by the factory value of resistor R108 and the OUTPUT DEVIATION control. This 8,0 volt point supplies the reference current to the compensation amplifier and the current to the standard cell standardizing circuit. The standard cell amplifier and panel meter are calibrated for ± 10.18 mv and ± 2.59 mv to end scale and are set up to read zero when -8,000 volts exist between TP1 and TP3. The panel meter, therefore, reads $\pm 1\%$ and $\pm .25\%$ depending on the position of the meter function switch and indicates the equipment output voltage (or current) as % deviation from the set value as controlled by the ten turn OUTPUT DEVIATION potentiometer. In the NULL position of the METER FUNCTION switch the input to the standard cell amplifier is connected to common and the meter zeroed with the off set control of the chopper amplifier R29, NULL ADJUST potentiometer. In the SERVO position, the meter is switched to the output of the compensation amplifier and indicates the operating condition of the servo loop. For proper operation on SERVO the meter should read in the region between $-.15\%$ and $+.15\%$ on the $\pm .25\%$ scale.

In the OPERATE position of the STANDBY-OPERATE switch the signal from the Voltage Output Unit is connected to the input of the rectifier amplifier and accurately rectified to half wave pulses. Three DC pulses are compared with the -8,000 volt reference point by high resistance networks and the difference applied to the input of the compensation amplifier. The compensation amplifier is basically an integrator with a sensitivity and off set stability in the order of ± 50 microvolts which enables the amplifier to detect a change of one part in 10^5 in the signal pulses. Capacitor C105 controls the integration constants, and C104 and resistor R120 control the transient response of the regulator system. Limiter circuits are provided around the operational amplifier so as to hold the amplifier in operating condition during loss of signal or misoperation of equipment. Zener (22V) CR103 and CR104 with diodes CR105 to CR108 limit the output of the compensation amplifier to ± 22 volts.

The potentiometer R106 in the reference resistance to the compensation amplifier controls the calibration of all ranges of the Output Unit.

The voltage controlled oscillator is set up so that change of -15 volts DC to +15 volts DC output from the compensation amplifier changes the voltage controlled oscillator output from 7 volts AC to 14 volts AC. The nominal output with zero DC input is 10.00 volts.

This 10 volts AC is applied to the preamplifier and power amplifier. The gain of the combination is adjusted by the PREAMP control for 18 volts output to the output transformer network for the Voltage Standard and 2.0 amperes output for the Current Standard.

In the STANDBY position of the STANDBY-OPERATE switch, the 10V output from the oscillator is switched from the pre-amplifier directly to the rectifier amplifier so as to keep the servo circuits in their operating regions when no power is being applied to the output.

POWER SUPPLY

The power supply consists of two complete regulated supplies, one for -50 volts at 2.0 amps. max. and one for +50 volts at 2.0 amps. max. Potentials of -28 volts and +28 volts at 0.2A are dropped from the ± 50 volts with series type transistor regulators. Figure 16 shows the schematic diagram of the power supply. With reference to the +50 volt regulator, Q7 and Q8 are power transistors used as series regulator elements. Transistor Q4 is an emitter follower driving the series elements. Q1, CR1 and associated components supply a constant current to the DC amplifier consisting of Q2 and Q3. Potentiometer R207 controls the +50 volt output of the regulator, and potentiometer R215 controls the -50 volt output. The -28V and +28V taps are held to value by zener diodes.

Transistors Q6 and Q11 act as current limiters. When the power supply is short circuited the current is limited to 30% above that necessary to blow the breaker. This gives the breaker time to blow without submitting the regulator transistors to destructive over currents. Potentiometers R212 and R205 set the limited value of current.

A line filter is mounted in the power supply chassis to filter high frequency transients from the AC line.

WATTS ACCESSORY PANEL

This module is used to frequency lock the Current Standard to the Voltage Standard at a 90° phase angle. Zero phase angle locks are also provided. Without the Accessory Panel the Current Standard will lock to the Voltage Standard at zero phase angle plus or minus 60 degrees. The addition of this accessory allows all phase angles (0 to 360°) to be covered for 50, 60, 400, 1000 and 2000 Hz or any frequency between 50 and 2000 Hz if an external capacitor box is used.

Ten volts from the Voltage Standard are fed into J1 of the accessory. Switch S1 allows the phase of the signal to be shifted 180°. Switch S2 selects either 0 power factor (90° phase shift) or 1.0 power factor (0°). The operating frequency is set by rotary switch S3. The 6.3 volts output is plugged into the Sync jack J101 of the control unit of the Current Standard.

A group of high frequency shunts are provided to use in measuring the phase angle of the current. The phase angle can be measured with an oscilloscope at zero phase angle and with a phase meter for other phase angles.

MAINTENANCE

INTERNAL REFERENCE CHECKS & ADJUSTMENT

The Model 100 Standards are equipped with two basic reference sources as a convenient and fast self-checking feature: an unsaturated standard cell and a temperature controlled zener diode. The standard cell is used as a primary reference and the zener diode as the working standard. Comparison of primary and working reference emf is made by means of an operational amplifier with the OUTPUT DEVIATION control and meter as difference indicator. When the OUTPUT DEVIATION control is set to the reading given in the calibration certificate, the percent difference between the standard cell and zener diode is indicated on the meter deviation scale (0.25% full scale range) and this difference should not exceed .005%. Each dial division of the OUTPUT DEVIATION control is equal to 0.002%. The certificate supplied with the Model 100 specifies the nominal setting of the dial for zero error between standard cell and zener diode emf. It is advisable, on either a weekly or bimonthly basis, to adjust the control until the deviation meter indicates less than .005% deviation (zero error) between these emf's and note the control setting.

If the setting necessary for zero error varies from the original setting (set forth on the certificate) by more than two divisions it will be necessary to check the standardization of the equipment. The zener standard may have drifted. This can be checked and corrected by using the standard cell circuit. The standard cell can be checked at the front panel by means of a precision laboratory potentiometer (absolute accuracy $\pm 0.001\%$) or by means of comparison against a saturated standard cell (absolute accuracy $\pm 0.001\%$) plus a lower accuracy potentiometer. The standard cell dial on the Model 100 should be set to agree with the measured emf of the cell. Then adjust the OUTPUT DEVIATION control for zero on the meter with the METER FUNCTION switch set to .25% F.S. Record this new control setting on the calibration certificate as the new reference position.

When a change in the OUTPUT DEVIATION control to achieve zero error exceeds ten divisions, the output voltage or current should be measured as set forth in the following paragraphs to determine the source of trouble.

FRONT PANEL CIRCUIT TESTS

Table 2 gives the voltages and the purpose of measurements made at the respective test jacks of the control unit. Test point TP3 is the electrical common. This electrical common is carried through all the circuitry. It is grounded to chassis at one point (A4 terminal of the power supply). Test point TP1 is connected to the basic DC -8,000 volts reference point of the system. The AC output voltage of the Voltage or Current Output units is measured at TP2. The half wave output of the rectifier amplifier may be observed on TP4. The output of the compensation amplifier is observed on the panel meter when the METER FUNCTION switch is in the SERVO position. The output of the voltage controlled oscillator is measured at TP7 and the power amplifier output is measured at test point TP5.

The trouble shooting measurements of Table 2 should be made with an accurate AC-DC differential voltmeter with $\pm .01\%$ accuracy on DC and 0.1% accuracy on AC. An adapter should be used in the AC line of the instrument to open the third wire of the line cord. This will prevent circulating ground currents.

TROUBLE SHOOTING THE SERVO SYSTEM

When the METER FUNCTION switch is in the SERVO position the panel meter is reading the output of the compensation amplifier. This output is limited to ± 25 volts which corresponds to plus and minus full scale readings. Under normal operation this output may vary ± 5 volts to compensate for frequency range changes, voltage ranges and load variations. Mis-operation or failure of the equipment will usually result in an end scale reading of the panel meter.

If a failure occurs, return to STANDBY position of the STANDBY-OPERATE switch and check if the loop operates in STANDBY by observing whether the panel meter returns to center position (SERVO position). If the equipment operates in STANDBY, the trouble should be looked for in the pre-amplifier, power amplifier or Output Unit. If the equipment does not operate in STANDBY, the trouble probably will be found in either the power supply, rectifier amplifier, compensation amplifier or oscillator.

The power supply breaker and fuses should be checked first. The breakers and fuses are set close to the rated load values and may blow on overload. Turn off the line switch and reset breakers and check and replace fuses; try to restart once if breakers or fuses are blown. Remove 3A power amplifier fuses and turn on. This removes the power amplifier from the main supply and could indicate a transistor failure in the power amplifier. Failure of the breakers to remain closed with both 3A and $\frac{1}{2}$ A fuses removed requires removal of the Control Unit chassis from the cabinet and the testing of all power transistors in the power supply.

Measure currents and voltages associated with the power supply at the front panel test pins before placing back in service.

If removal of the 3A power amplifier fuses corrects the loading of the power supply, test all the power transistors in the power amplifier.

Signal tracing of the servo loop is accomplished by plugging an external oscillator into front panel jack J1 and setting its level to near 3.33 volts at 100 Hz. This signal is then followed to the output of the oscillator unit (TP7 at 10.00 volts), to test point TP5 at output of power amplifier (18.0 volts), to output of the Output Unit at test point TP2 (9.00 volts for Voltage Standard, 3.880 volts for Current Standard), to output of rectifier amplifier (TP4, clean $\frac{1}{2}$ wave, 14.14 volts peak). Normal operation of the compensation amplifier is indicated if the output of the external oscillator can be adjusted so as to keep the panel meter on

TABLE 2

Test Jack Measurements

TEST POINTS	PURPOSE	READING
TP1 to TP3 (TP3 is Common)	Measure -8,000 reference voltage of servo system.	-8,000 $\pm$.01% VDC (see calibration data for exact value).
TP2 to TP3 (TP3 is Common)	Measure output of Voltage or Current Output Unit. Scope should show clean sine wave.	9,000 $\pm$.1% VAC on Voltage Standard. 3,880 $\pm$.1% VAC on Current Standard.
TP4 to TP3 (TP3 is Common)	Measure output of rectifier amplifier. Scope pattern is a clean $\frac{1}{2}$ sine wave.	14, 14 volts peak 4.5 volts average
TP5 to TP3	Output of power amplifier. Clean sine wave, OPERATE condition, no load.	18.0 volts AC on Voltage Standard. 4.0 volts AC on Current Standard.
TP6 to TP3	Measures the voltage across field effect transistor for setting the voltage controlled oscillator in its operating range.	.075 - .085 volts AC.
TP7 to TP3 (TP3 is Common)	To measure output of oscillator amplifier.	10.00 $\pm$ 2% VAC at 100 Hz.
TP8 to TP3 (TP3 is Common)	Measure negative power supply for operational amplifiers.	-28 volts DC $\pm$ 5%.
TP9 to TP3 (TP3 is Common)	Main negative power supply voltage for power amplifier.	-50 volts DC $\pm$ 2%.
TP9 to TP10	Measure potential drop across 2 ohms to indicate current flow. Measure with Model 270 Simpson or equal, no load.	1.5 VDC on Voltage Standard. 3.0 VDC on Current Control Unit.
TP11 to TP12 (TP11 is +)	Measure potential drop across 2 ohms to indicate current flow. Measure with Model 270 Simpson or equal.	1.5 VDC Voltage Standard. 3.0 VDC Current Control Unit.
TP12 to TP3 (TP3 is Common)	Main positive power supply voltage for power amplifier.	+ 50 volts $\pm$ 2% VDC.
TP13 to TP3	Positive power supply voltage for operational amplifiers.	+ 28 VDC $\pm$ 5%.
TP14 to TP3	Output of compensation amplifier.	$\pm$ 20 VDC.

scale. This signal tracing test can be carried around the entire servo loop with the STANDBY-OPERATE switch in OPERATE position or around the standby loop in the Control Unit. When the sub-assembly causing trouble is located, all transistors should be tested, taking care to replace each transistor in its original position. This will usually locate the failure.

ALIGNMENT & CALIBRATION

After a major overhaul or as a trouble shooting procedure, the following alignments and calibrations can be made to ensure over-all performance. These alignments and calibrations can best be accomplished with the cabinet cover removed from the frame by removing the eight screws around the bottom edge.

ALIGNMENT OF POWER SUPPLY

Start the test of the power supply under no load conditions, R212 and R205 in full counterclockwise position.

1. Adjust R215 for -50V DC at terminal A6.
2. Adjust R207 for +50V DC at terminal A1.
3. Connect a 200-watt 10-ohm resistor with a 5.0 ampere DC ammeter in series across the +50 volt terminals (A1 to A3).
4. Adjust R205 so that breaker CB201 just trips. This will be between 3.0 and 3.7A.
5. Check that placing a 15-ohm resistance across the +50 volt terminals does not trip the breaker.
6. Check that less than 10 ohms (5 ohms, 2 ohms and direct short) trip the breaker.
7. Repeat steps 3 to 6 inclusive for the negative power supply to adjust R212 (A3 to A6).
8. Check that the output ripple of each 50-volt supply is less than 250 microvolts at 1.0-ampere load.

OSCILLATOR CONTROL UNIT

1. Disconnect the wire from terminal E6 of the oscillator control unit and connect E6 to the center tap of an external 100,000-ohm potentiometer. Connect the outside terminals of this potentiometer to terminal E1 (+28V) and E2 (-28V) to obtain a variable DC control voltage for the oscillator.

2. Turn ON the equipment and set the voltage at terminal E6 to zero with a high impedance DC voltmeter. Connect an AC vacuum tube voltmeter (Ballantine Model 300 or equal) and oscilloscope to TP7 with TP3 as common. Connect another vacuum tube voltmeter to TP6 with TP3 as common. Line cords of all test equipment should have adaptors so as to break the grounding pins.

3. Set the oscillator dials to 50 Hz (0.1 range) and adjust R45 for 10V AC out at TP7. Note the reading of voltmeter at TP6. If above 80 mv, adjust R31 so as to in-

crease the reading 10%, then reset output to 10 volts with R45. Note that voltage at TP6 moves down. Continue adjustments until the voltage at TP6 is 80 mv for 10 volts output. If original reading is below 80 mv, adjust R31 to decrease reading at TP6, then reset R45 for 10 volts out and continue until TP6 voltage is 80 mv. R31 may be reached with a long screw driver from the side of equipment. R45 is available at side of oscillator unit and requires a #4 hex wrench to adjust.

4. Set the oscillator dials to 500 Hz (1 range) and adjust R46 for 10 volts output.

5. Set the oscillator dials to 5000 Hz (10 range) and adjust R47 for 10 volts output.

6. Check that the output voltage at TP7 remains at 10.0 volts ± 0.5 volt for all 1st dial positions on each frequency range.

7. Measure the harmonic distortion at TP7 with a Model 331A Hewlett-Packard Distortion Analyzer or equal. Adjust R14 for minimum distortion. Check that distortion remains below .025% at low, center, and high end of each frequency range.

8. Check the DC input to AC output control range by varying the external 100,000-ohm potentiometer between -15 volts and +15 volts. At -15 volts DC input, the AC output is 7.0 volts ± 1 volt. At +15 volts DC input, the AC output is 14 volts ± 2 volts.

9. Failure of the oscillator unit to adjust to the above specification requires internal trouble shooting and testing of semiconductors.

ADJUSTMENT OF PRE-AMP POTENTIOMETER R126

The purpose of this adjustment is to set the output voltage of the oscillator to 10 volts for both STANDBY and OPERATE conditions.

1. Operate the equipment on any convenient voltage range at 100 Hz.
2. With the METER FUNCTION switch set to SERVO position adjust PRE-AMP control until the panel meter does not move between STANDBY and OPERATE condition.

ADJUSTMENT OF RECTIFIER AMPLIFIER & COMPENSATION AMPLIFIER OFFSET CONTROLS R29

1. Place equipment in the STANDBY position.
2. Open terminal F1 of the oscillator unit and pull out the constant temperature oven. This removes the AC signal to the input of the rectifier amplifier and the reference current to the compensation amplifier.
3. Read the DC voltage on test point TP4 with a potentiometer or null detector sensitive to less than 1 millivolt. Test point TP3 is common.
4. Adjust control R29 of the rectifier amplifier for null detector zero at TP4.

5. Read the DC voltage on TP14 to TP3 at common with a potentiometer or null detector sensitive to less than 1 millivolt.

6. Adjust control R29 of the compensation amplifier for null detector zero at TP14.

VOLTAGE CONTROL UNIT ADJUSTMENTS (Given for reference; should only be necessary after major repair)

The adjustments in the Control Unit are set in the STANDBY condition and may be readjusted in the final calibration. Connect precision resistance decade boxes in the circuit for R108 and R105 on calibration resistor terminal board. This board is behind front panel test points and can be reached by removing four screws.

1. Operate the equipment in STANDBY at 100 Hz.
2. Set the CALIBRATE control R106 in center position; set the OUTPUT DEVIATION control R107 in center position (500). Test point TP3 is common for all measurements.
3. Adjust R108 for $-8,000 \pm .02\%$ DC at TP1 as measured with an accurate differential DC voltmeter. (The panel meter will read zero on the .25% scale at the $-8,000$ V DC value. This checks the standard cell dial and the standard cell.)
4. Adjust R105 for 9,000 volts AC at test point TP2, measured with an accurate ($\pm 0.1\%$) AC differential voltmeter.
5. Replace decade boxes with precision fixed resistors.

ALIGNMENT OF CURRENT OUTPUT UNIT (Given for reference; should only be necessary after major repair)

Operate the Model 100 Current Standard at 100 Hz to deliver 2,000 amperes to a 2.5-ohm resistor. Connect a switch across the 2.5-ohm resistor to short out this resistor for no load readings. Connect a recently calibrated Model 1605A AC-DC Calibration/Transfer Standard (or equivalent current measuring device accurate to $\pm .01\%$) in series with the 2.5-ohm load resistor. The burden of this standard should be less than 4.0 watts (total burden less than 14 watts). With reference to Figure 13, the potentiometer R301 feeds an immediate correction back to the input of the amplifier to hold constant current for variation in output burden; R302 and R303 feed corrections to the integrator loop which requires time to correct.

1. Set the Model 1605A to read the deviation of the 2.0-ampere output on the galvanometer.
2. Switch the burden off and on and adjust R301 so that the initial output current change on a change of burden is nulled out. Then adjust R302 so that the long time change of output current due to change of burden is nulled out. Disregard changes in the absolute value of the 2.0 amperes. When R301 and R302 have been set, record the 2.0-ampere $\pm 0.1\%$ reading and the voltage at TP2 ($3,880 \pm 0.1\%$). Change R315 to bring within tolerance.

3. Operate the Current Standard to deliver .05 ampere and set up the Model 1605A to read deviation from this

value. The burden resistor is now 1000 ohms.

4. Switch the burden off and on and adjust R303 for long time correction of output current due to burden change.

5. Set R304 to give the same absolute error on the .05A range as existed on the 2.0A range at the end of step 1.

6. Set the Model 100 Current Standard on absolute calibration by operating the equipment to deliver 2,000 amperes at 100 Hz and adjusting the Control Unit. Adjust the CALIBRATE control R106 until the current output reads 2,000. If R106 does not calibrate at the center $\pm 20\%$ of its range, readjust the fixed resistor R105. Check the $-8,000$ V DC between TP1 and TP3 and set with OUTPUT DEVIATION control R107. Readjust R108 if R107 is not centered ± 20 divisions. Check standard cell settings and calibration.

7. Return to the Current Output Unit and recheck the adjustments of R301, R302, R303, and R304.

8. When operating down-scale on the 2.0A range at 1000 Hz, determine values of shunting resistors with a decade box that pulls the output on value for each of the 1st four steps for an output burden of 4 watts (the burden of the Model 1605A). Solder in fixed resistors for R311, R312, R313, and R314.

9. Replace cabinet cover and check calibration.

ALIGNMENT OF VOLTAGE OUTPUT UNIT

Operate the Model 100 Voltage Standard at 100 Hz to deliver 100.0 volts to a 1000-ohm burden resistor (100 W type). Connect a recently calibrated Model 1605A AC-DC Calibration/Transfer Standard or equivalent AC measuring device across the output. See Figure 14.

1. Set the Model 1605A to read the deviation of the 100.0 volt output on the galvanometer. Connect the 10-watt burden on and off and adjust R402 for null initial deflection between load and no load.

2. With 500 ohms across the output (20VA) set R416 for full scale output on the VA output meter.

3. With equipment in STANDBY, set potentiometer R438 to center of its range; connect a decade box in the circuit for R403. In OPERATE condition, adjust R403 for 100.00 volts output (no load) to accuracy of Model 1605A.

4. Calibrate 1000-volt range with R426; 500-volt range with R32; 200-volt range with R436; 50-volt range with R440; 20-volt range with R442; 10-volt range with R444, and MV ranges with R445.

5. Operate equipment at 7 kHz and no load on the 10-volt range. Adjust C409 with dial 1 at 10 position for 10,000 volts out. Adjust C410 for dial 1 at 9 position for 9,000 volts. Continue adjustments for C411 to C418.

6. Check the calibration at 10 kHz at full scale of each range. Adjust shunting capacitors (C419, and C420) to pull the 500-volt and 1000-volt ranges on value at 10 kHz.

TABLE 3

Performance Tests & Specification of Subassemblies

OSCILLATOR CONTROL UNIT HB-20050

Supply Voltage: +28 volts DC and -28V DC at 20 ma.

External Oscillator Signal: 3.33 volts $\pm 3.0\%$.

DC Control Signal: +15 to -15 volts DC.

AC Output Voltage: 7VAC ± 1 volts for -15VDC control signal, 10.0 $\pm .5$ volt VAC for 0VDC on all frequency ranges and dial positions, 14VDC ± 2 volt for +15VDC control signal.

Distortion of AC Output Signal: .025% at 10.00VAC.

Transmission Frequency Response: 3 db rise max.
(AC output vs. frequency DC control)

Transmission Frequency Response 3 db cut-off:

50 Hz on (X. 1) Range	2 Hz
100 Hz on (X. 1) Range	2 Hz
100 Hz on (X1) Range	2 Hz
1000 Hz on (X1) Range	15 Hz
1000 Hz on (X10) Range	20 Hz
10000 Hz on (X10) Range	100 Hz

Voltage on Field Effect Transistor drain (terminal 7):
75 to 85 millivolts.

RECTIFIER AMPLIFIER HB-20025

Power Supply Required: +28VDC and -28VDC at 15 ma.
115/6.3 volts 50/60 Hz.

Input Voltage: 9.000 volts AC on Voltage Standard
50 to 10,000 Hz.
3.880 volts AC on Current Standard.

Output Voltage: $\frac{1}{2}$ wave DC, 14.14 volts peak
 $\pm 1.0\%$, 50 to 10,000 Hz.

POWER AMPLIFIER HB-20090 & PRE-AMPLIFIER HB-20020 CURRENT STANDARD

Power Supply: +50 volts DC and -50 volts DC at
1.5 amperes.

Input Voltage: 10VAC 50 Hz to 3000 Hz.

Input Resistance: 24,000 ohms.

AC Output Current: 2.0 amperes (constant current).

Maximum Output Voltage: 15 volts AC.

Distortion: Less than .025%.

POWER AMPLIFIER HB-22680 & PRE-AMPLIFIER HB-22685 VOLTAGE STANDARD

Power Supply: +50 volts DC and -50 volts DC at
1.5 amperes.

Input Voltage: 10VAC, 50 to 10,000 Hz.

Input Resistance: 10,000 ohms.

AC Output Voltage: 18 to 22 volts.

AC Output Current: 1.5 ampere max.

Distortion: Less than .025%.

RANGE AMPLIFIER

Power Supply Required: +28VDC and -28VDC at 20 ma.

Gain: 1 to 10 depending on dial positions.

Input Voltage: 10 volts for gain of 1
1 volt for gain of 10.

Output Voltage: 10,000 $\pm .01\%$ volts AC.

Frequency Range: 50 to 10,000 Hz.

POWER SUPPLY HB-20080

Power Source Required: 115/230 volts, 50/60 Hz.

Positive Supply: +50 VDC at 2.5A
+28VDC at 0.2A

Negative Supply: -50VDC at 2.5A
-28VDC at 0.2A

Ripple: 250 μ V at 1.0A
1 mv at 2.0A

COMPENSATION AMPLIFIER INTEGRATOR CONNECTION

Power Supply Required: +28VDC and -28VDC at 15 ma.
115/6.3 volts, 50/60 Hz.

Input Offset: $\pm 50\mu$ V.

Integration Constant: 5 mv/sec. for 1.0 millivolt input.

Output DC Volts: ± 20 VDC, limited at 25VDC.

STANDARD CELL AMPLIFIER DC AMPLIFIER

Power Supply Required: +28VDC and -28VDC at 15 ma.
115/6.3 volts, 50/60 Hz.

Output DC: 1 volt.

NOTE: SWITCHES VIEWED FROM KNOB END
WITH SWITCH IN FULL CCW POSITION.

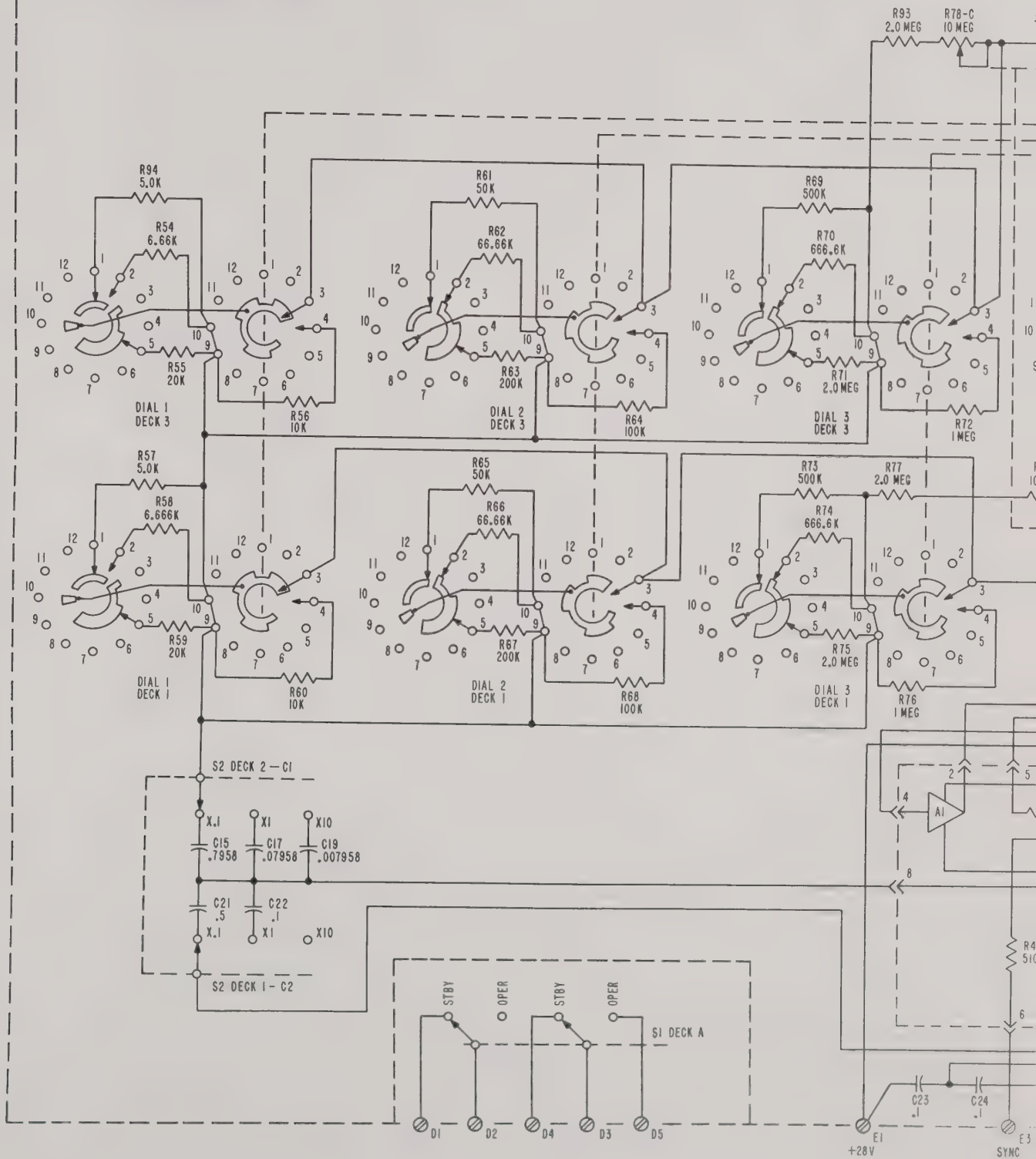
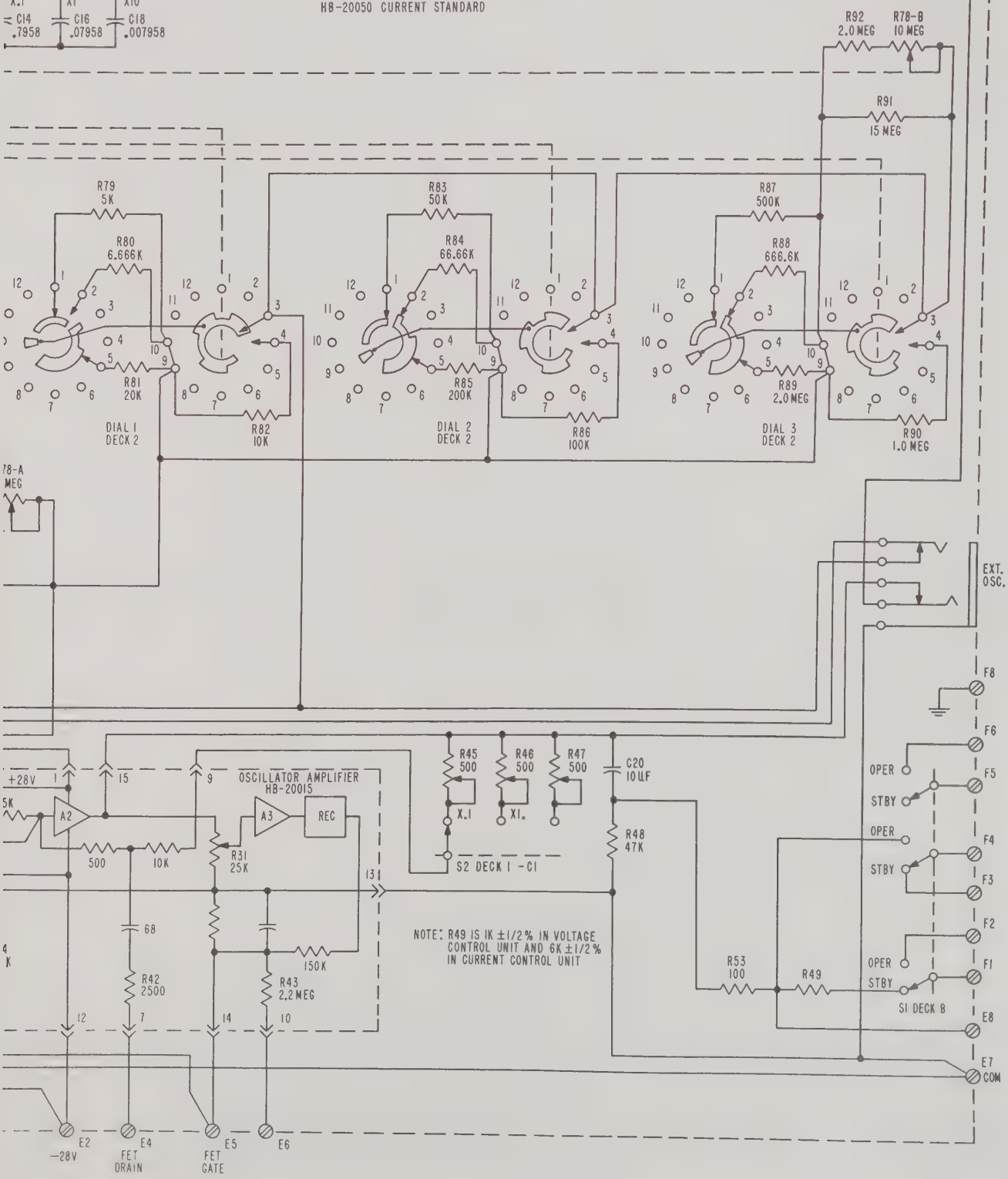


Figure 7.
Schematic Diagram of Oscillator Control Unit and View of Assembly.

S2 DECK 2 - C1

OSCILLATOR CONTROL UNIT
HB-22340 VOLTAGE STANDARD
HB-20050 CURRENT STANDARD



NOTE: R49 IS $1K \pm 1/2\%$ IN VOLTAGE CONTROL UNIT AND $6K \pm 1/2\%$ IN CURRENT CONTROL UNIT

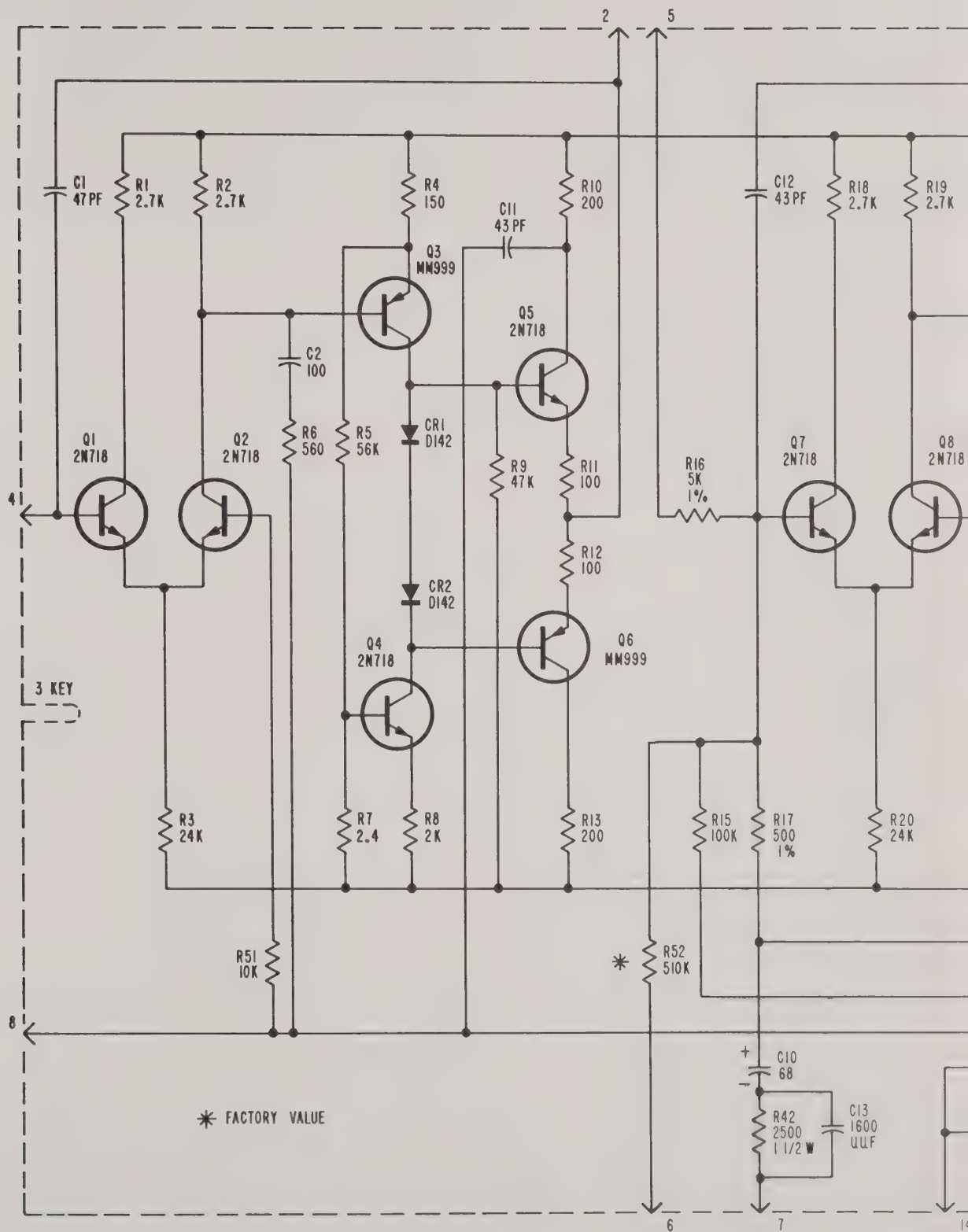
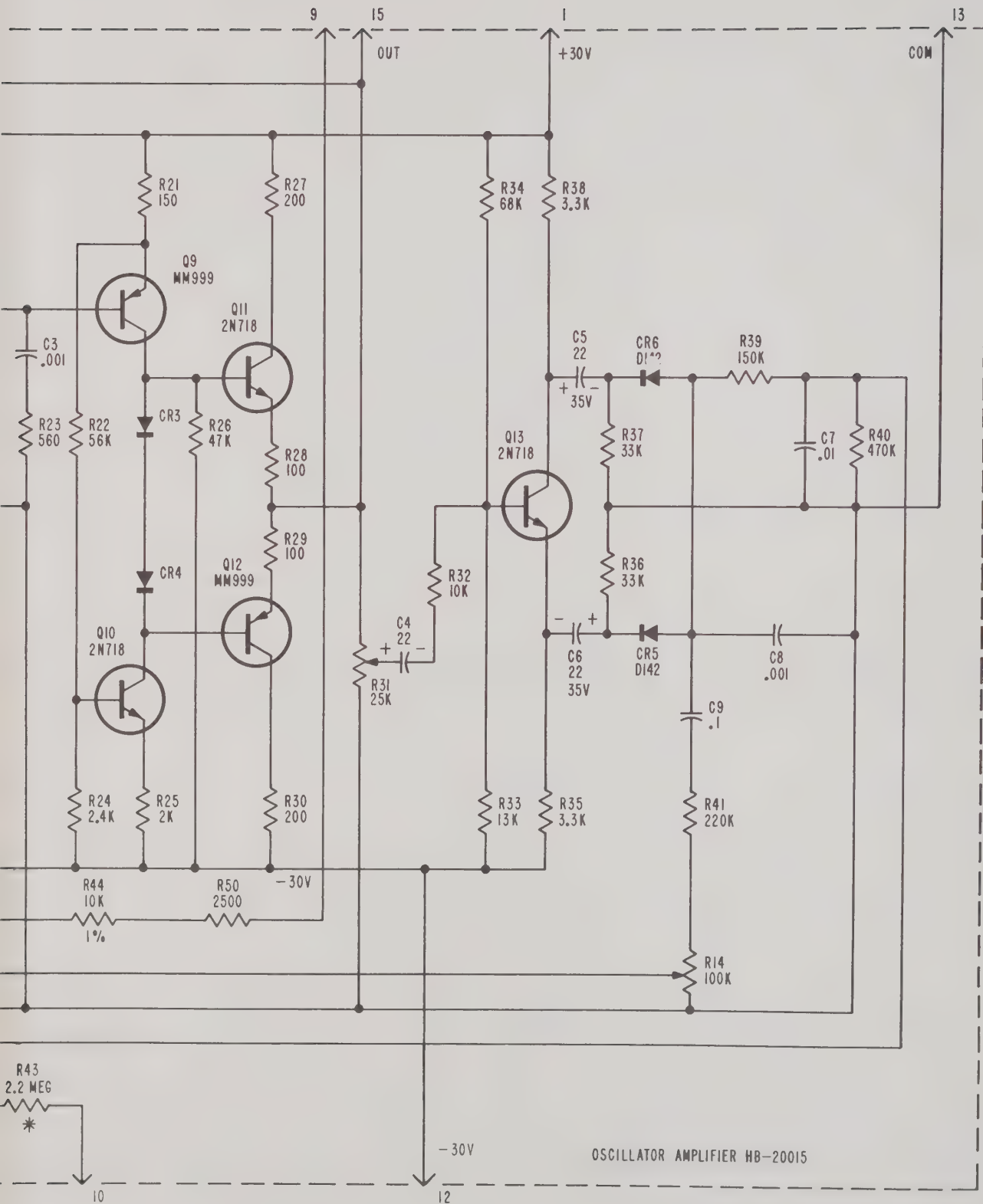
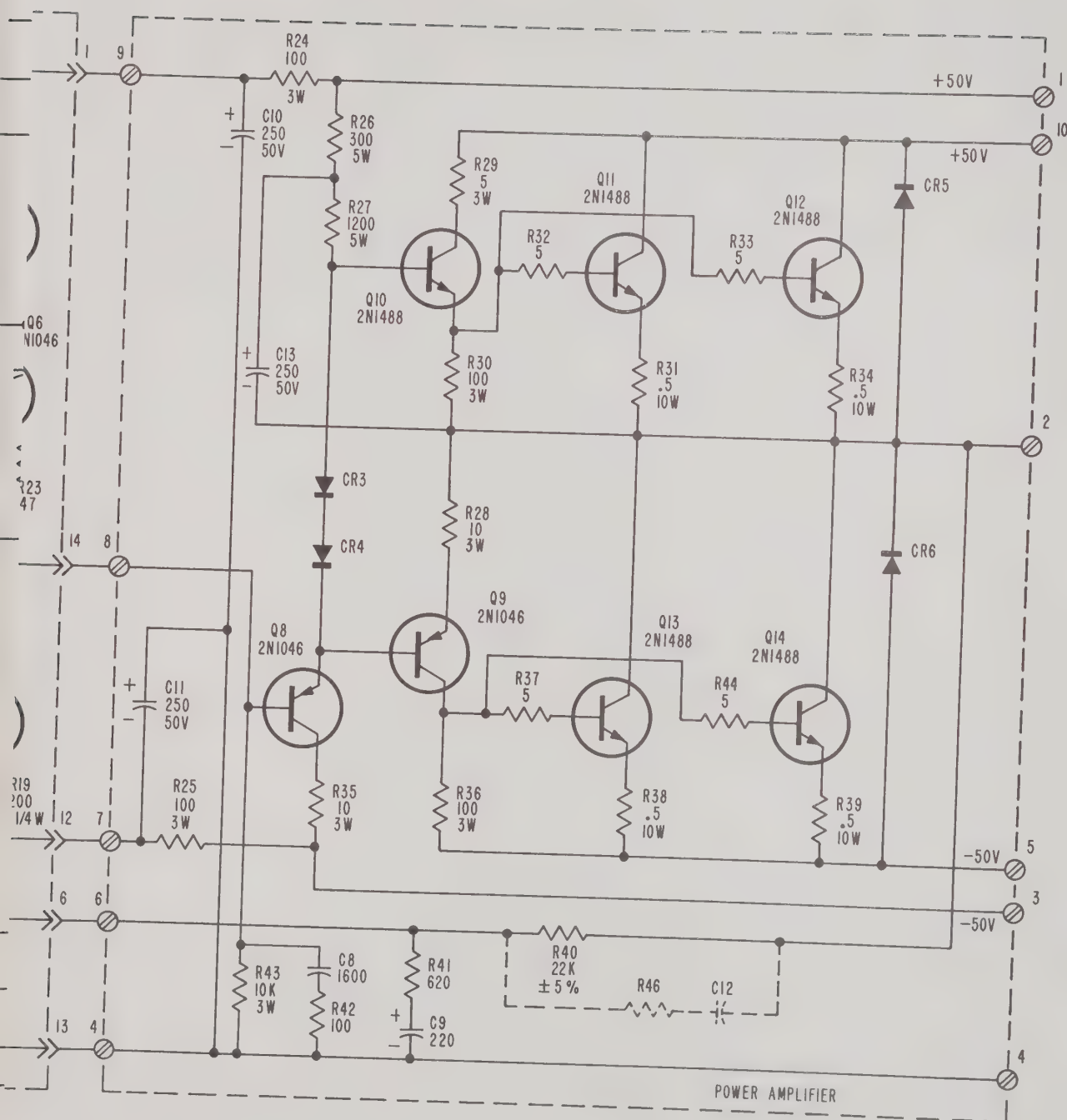


Figure 8.
Schematic Diagram and View of Oscillator Amplifier, HB-20015.





POWER AMPLIFIER	R41	R42	R46	C8	C12
VOLTAGE HB-22680	620	100	OMIT	1600uF	OMIT
CURRENT HB-20090	220	OMIT	4.7K	2000uF	.004 uF

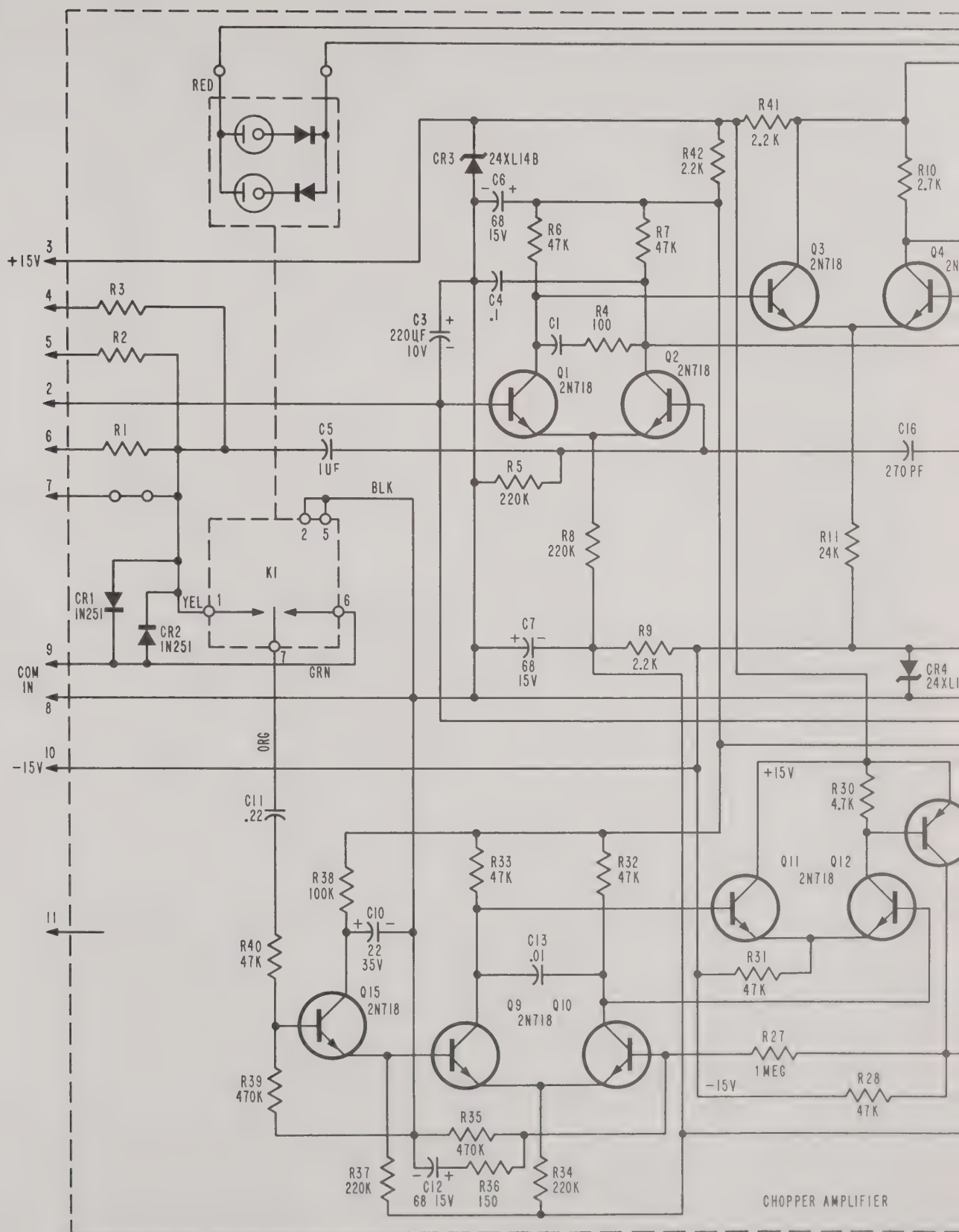
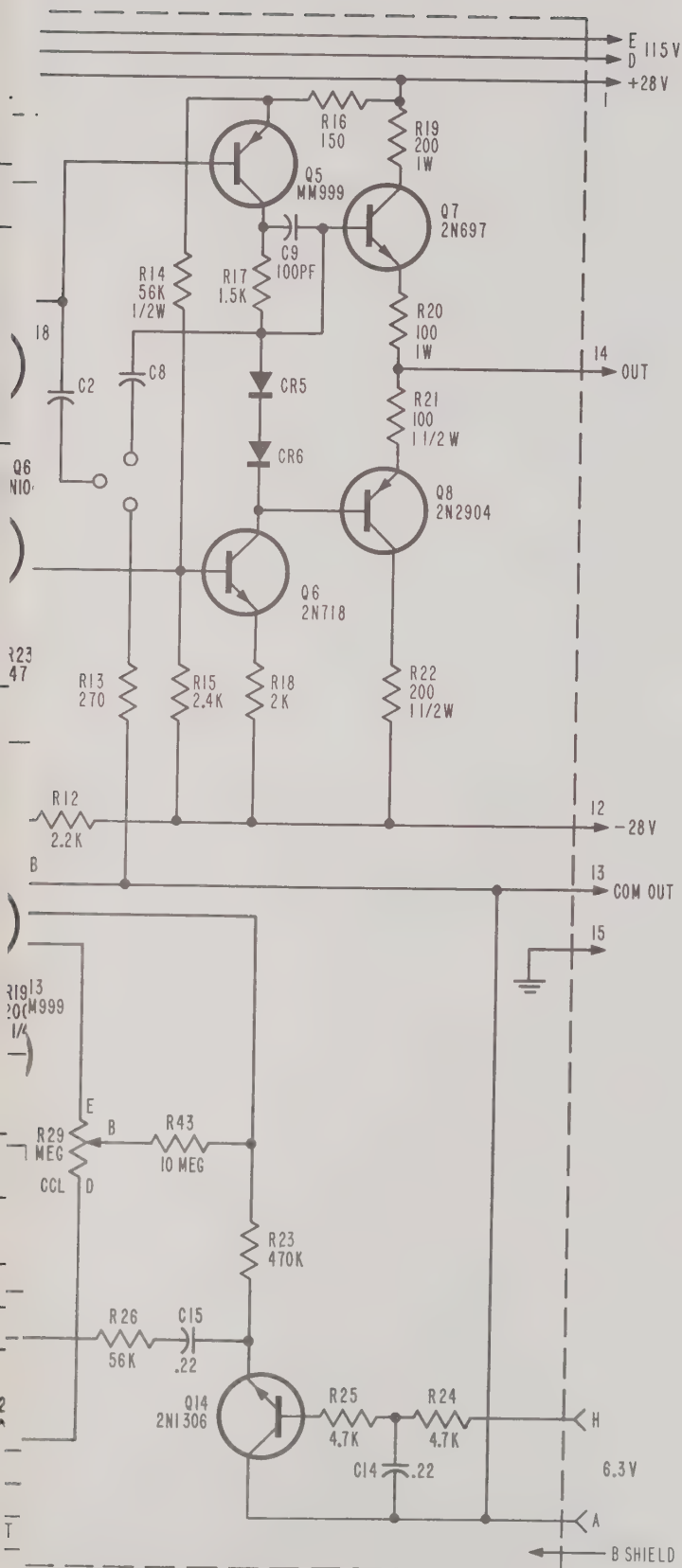


Figure 10.
Schematic Diagram and Views of Chopper Stabilized Amplifiers.



	R1	R2	R3	R4	C1	C2	C8
COMPENSATION AMPLIFIER HB-20070	75K	50K	100K	100	.068		1200PF
RECTIFIER AMPLIFIER HB-20075	9K	10K	10K	390	.0068	.0068	
STANDARD CELL AMPLIFIER HB-22370	100K	10K		100	.068		1200PF
RECTIFIER AMPLIFIER HB-20075-1	3.88K	10K	10K	390	.0068	.0068	

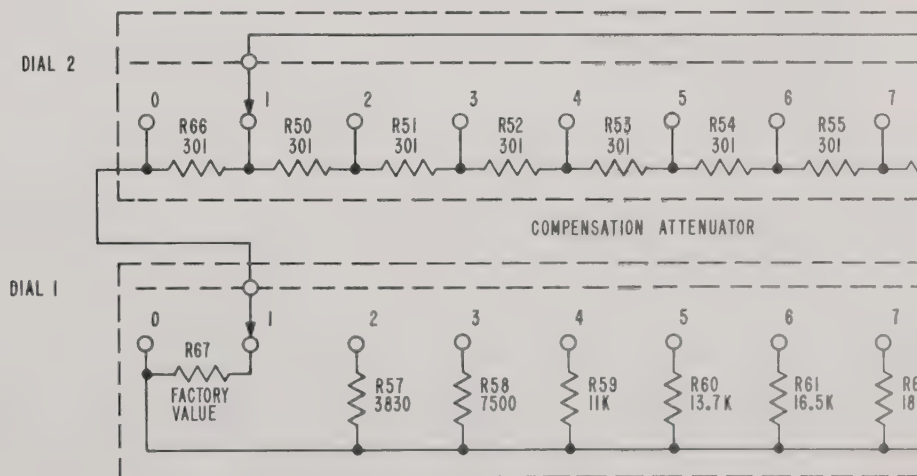
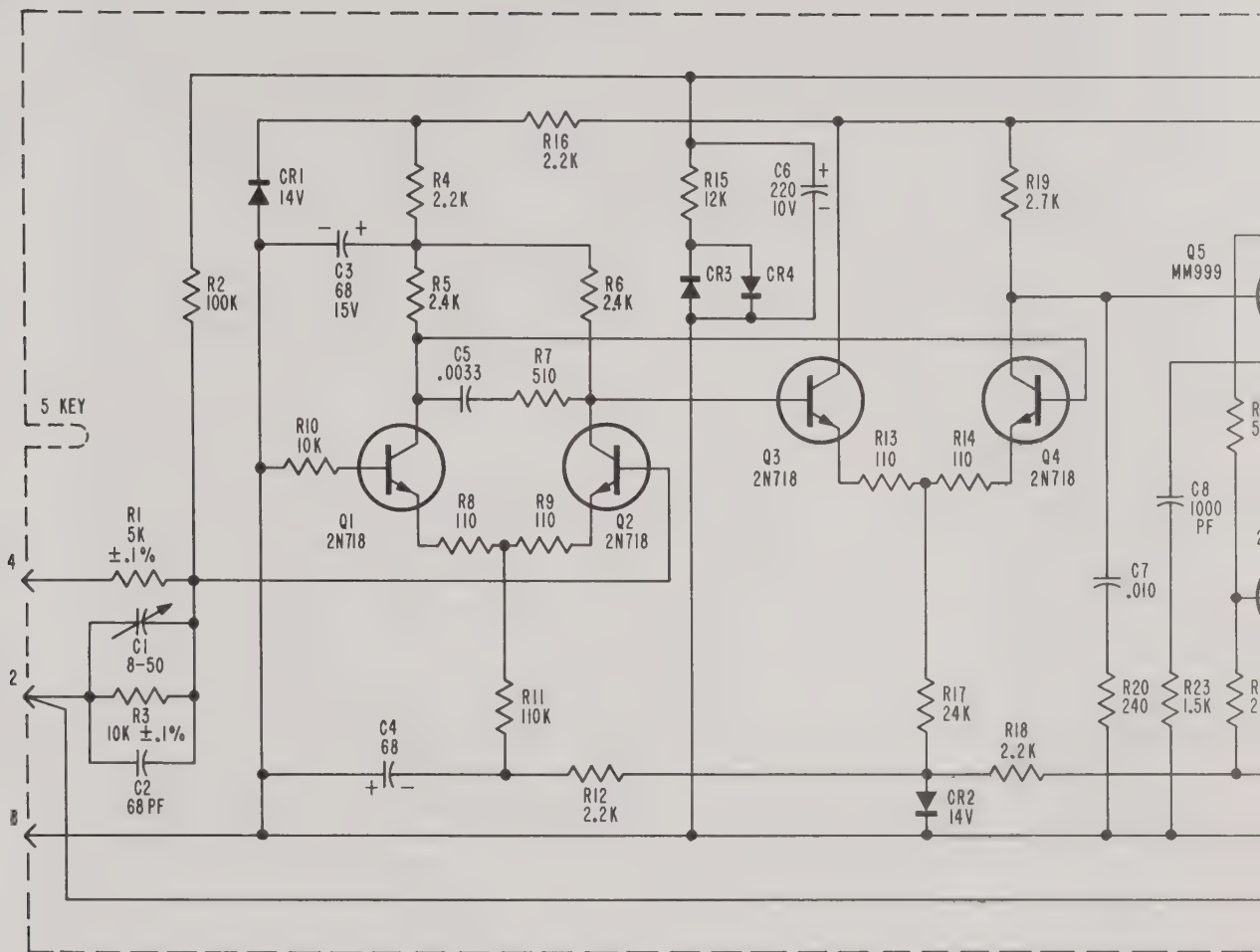
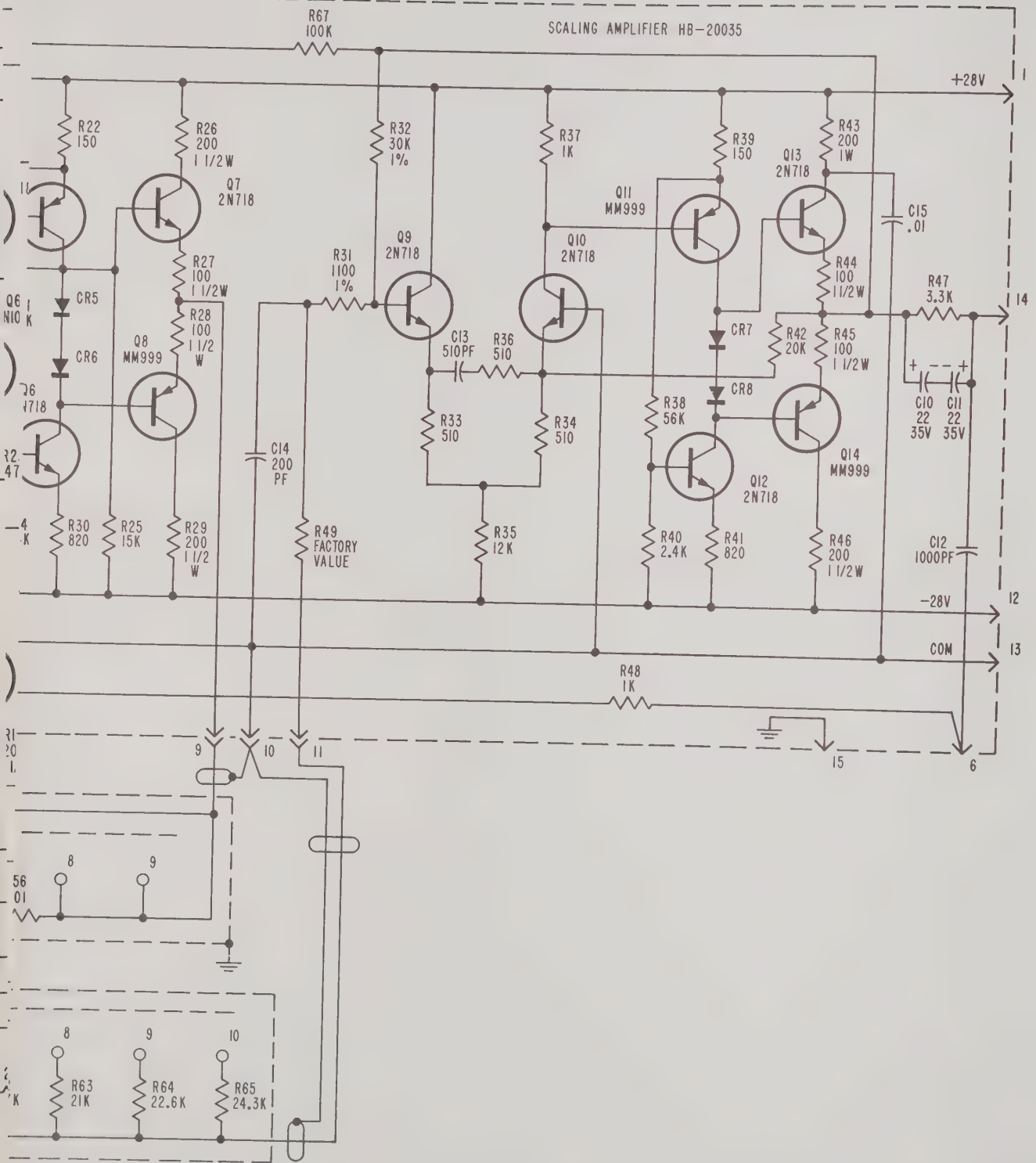


Figure 11.
Schematic Diagram and Views of Range Amplifier, HB-20035.

SCALING AMPLIFIER HB-20035



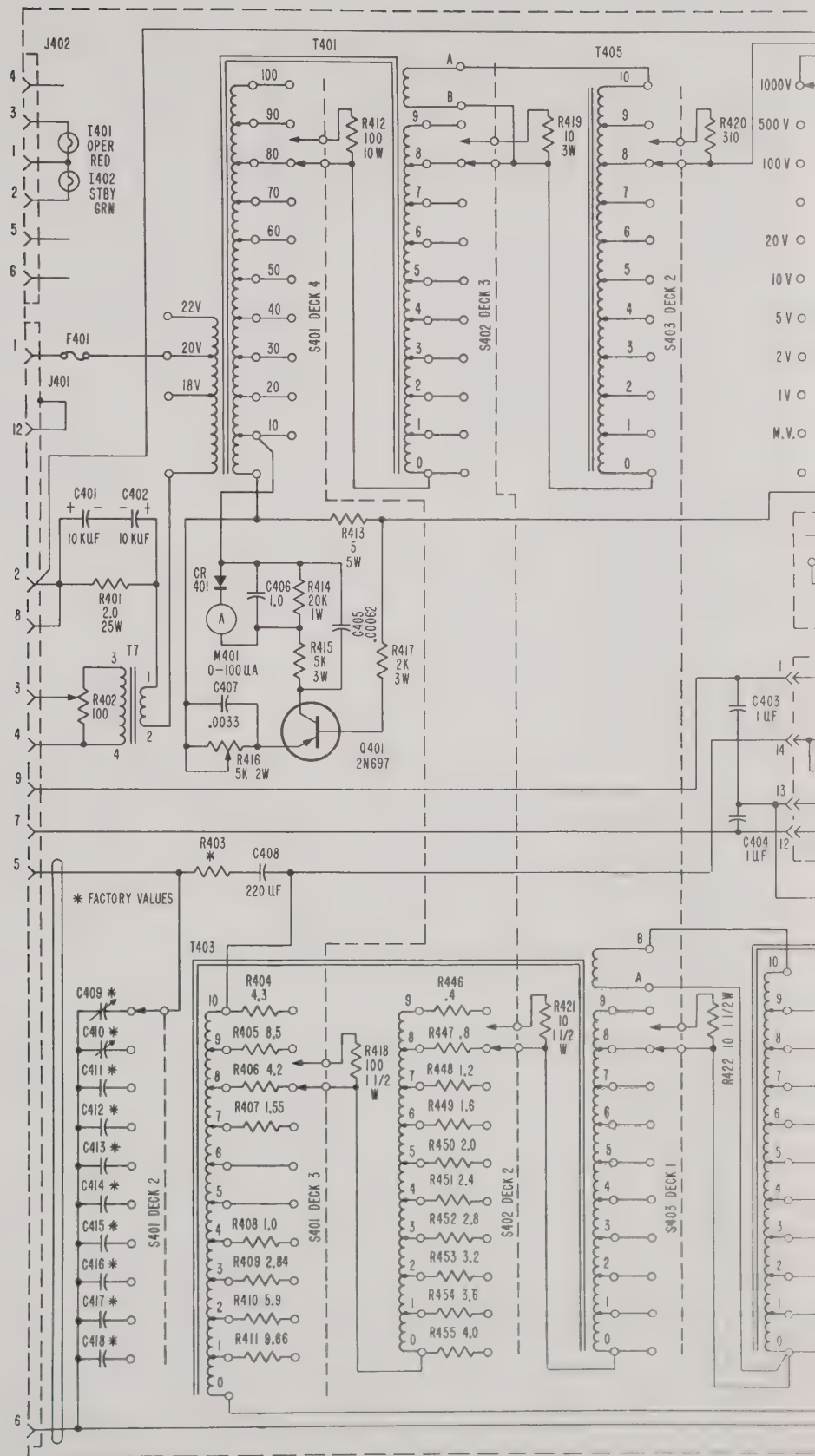
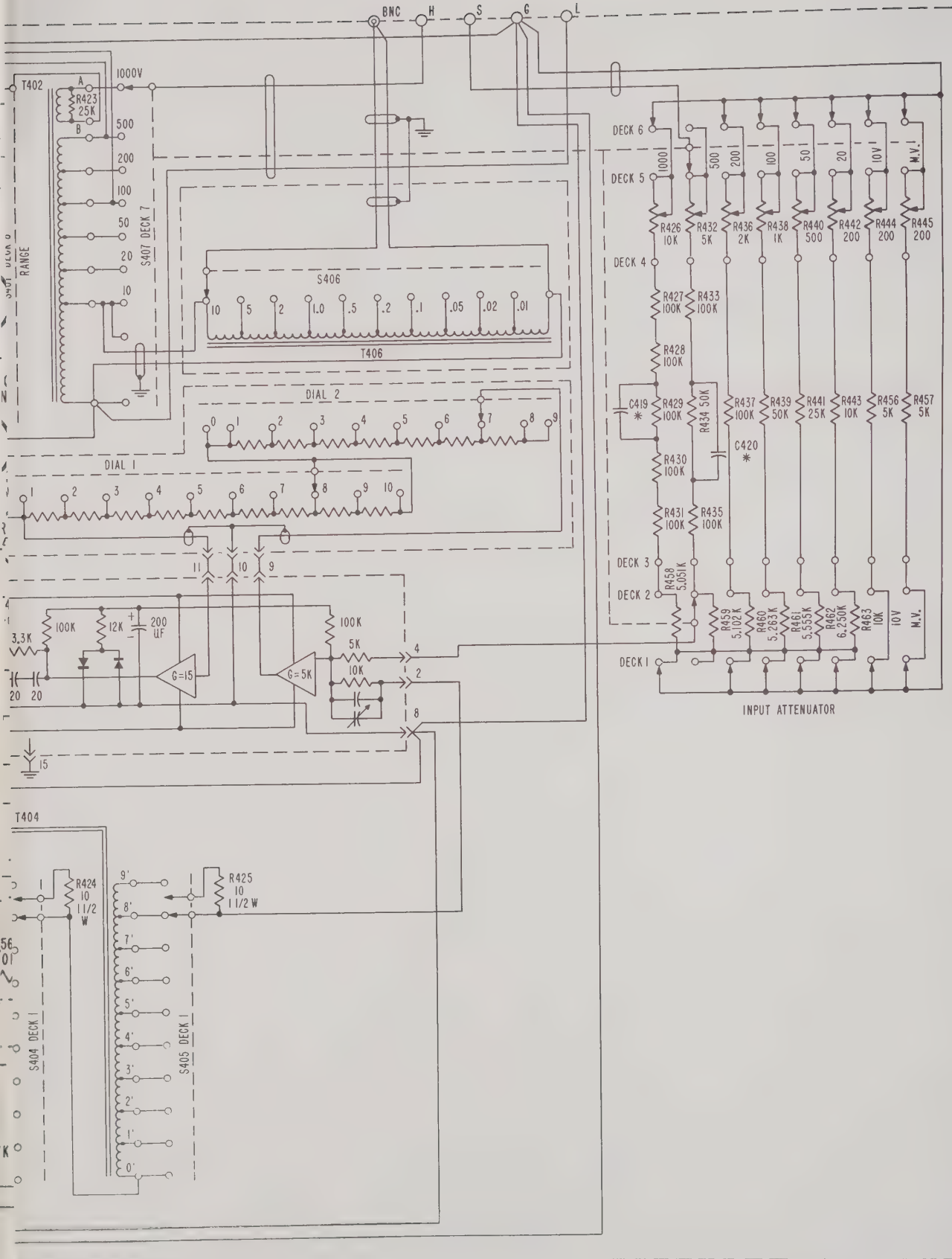


Figure 12.
Schematic Diagram and Views of Voltage Standard Output Unit, HB-22450.



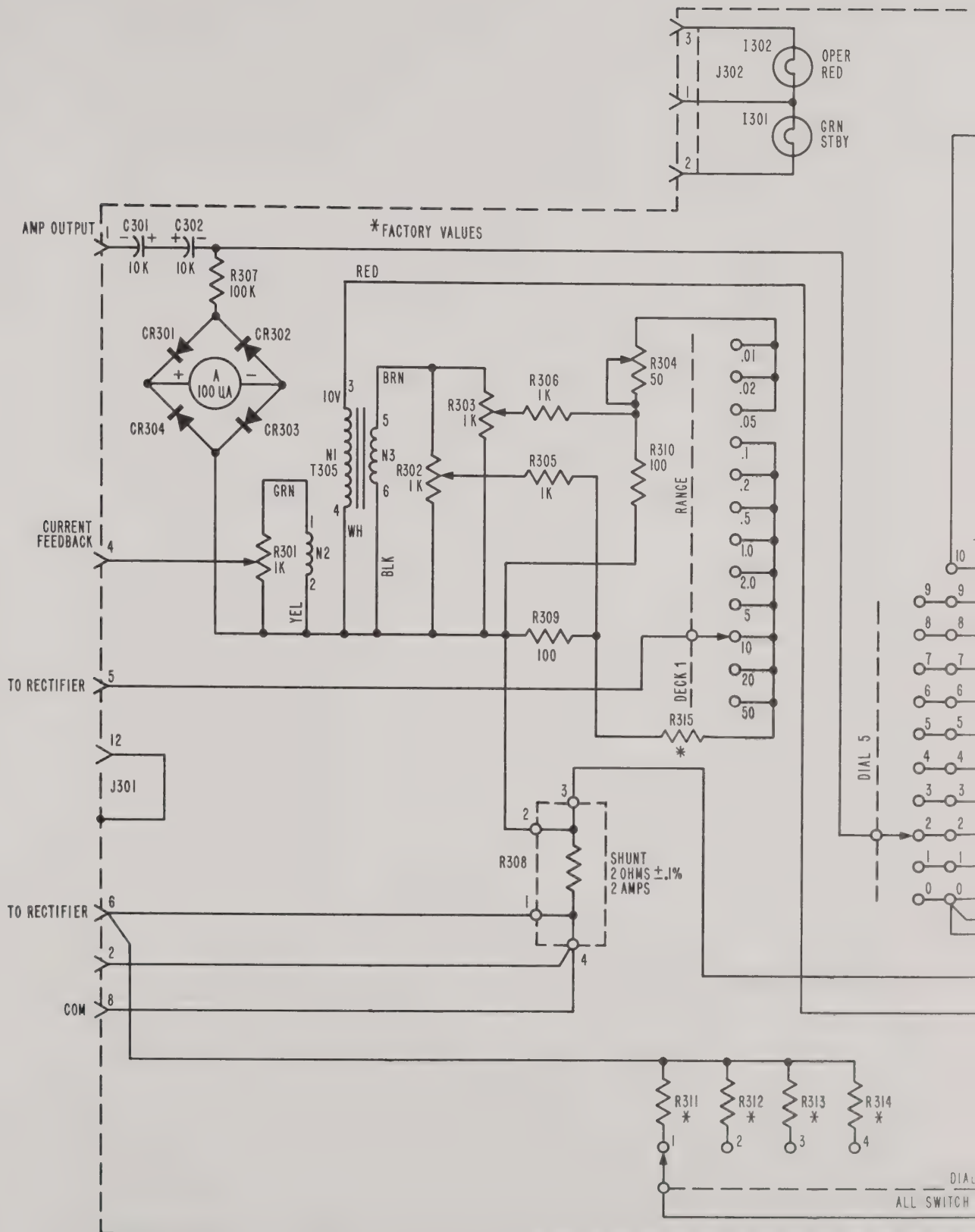


Figure 13.
Schematic Diagram and Views of Current Standard Output Unit, HB-22300.

3401 ULN 0

104

3.3

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20

10

10

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10

10

10

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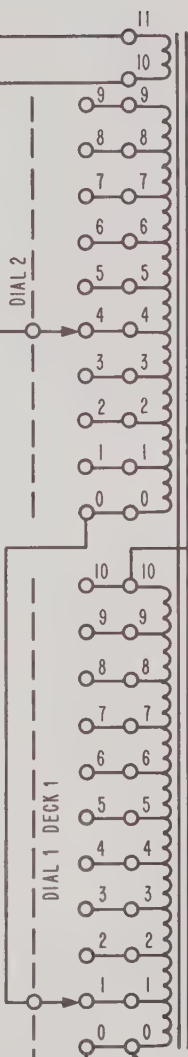
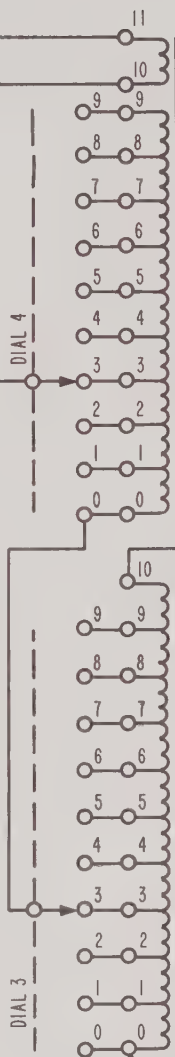
10

10

10

T303

T302



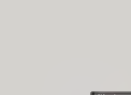
RANGE DECK 2



DECKS 4,5



RANGE



1-10A

20A

50A

COM

GND

1 DECK 2
SECTIONS OF SHORTING TYPE

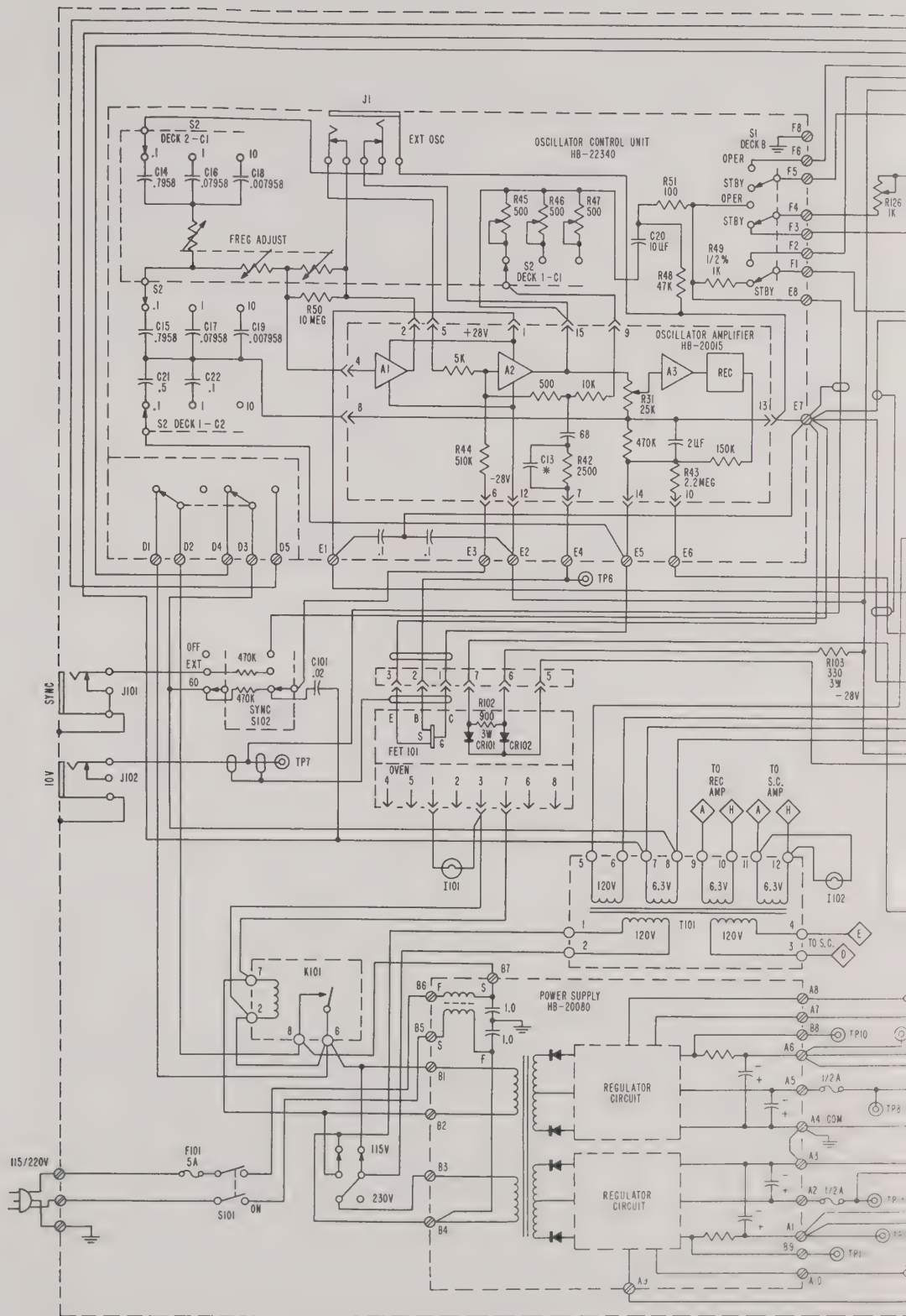
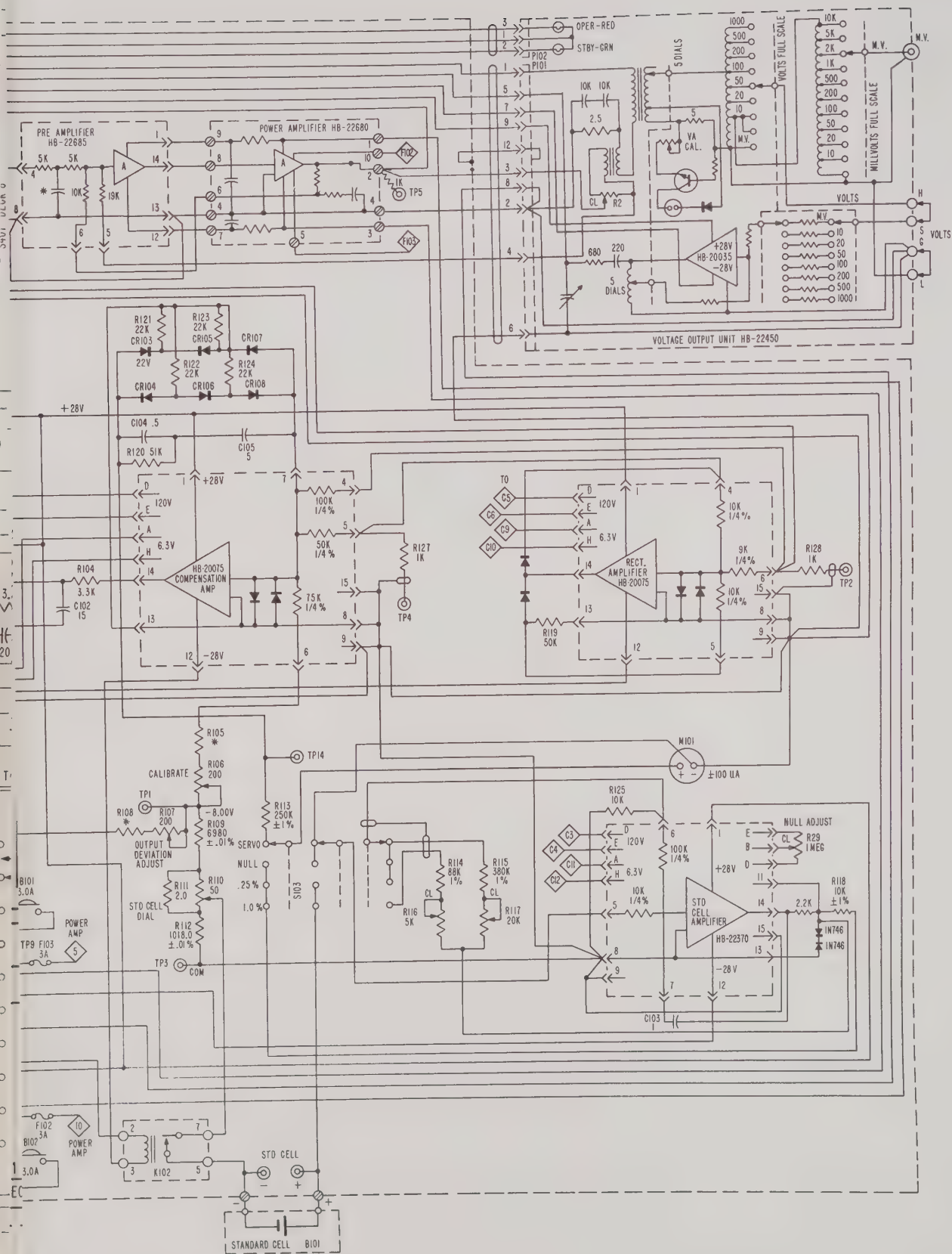


Figure 14.
Schematic Diagram of Voltage Standard Control Unit.



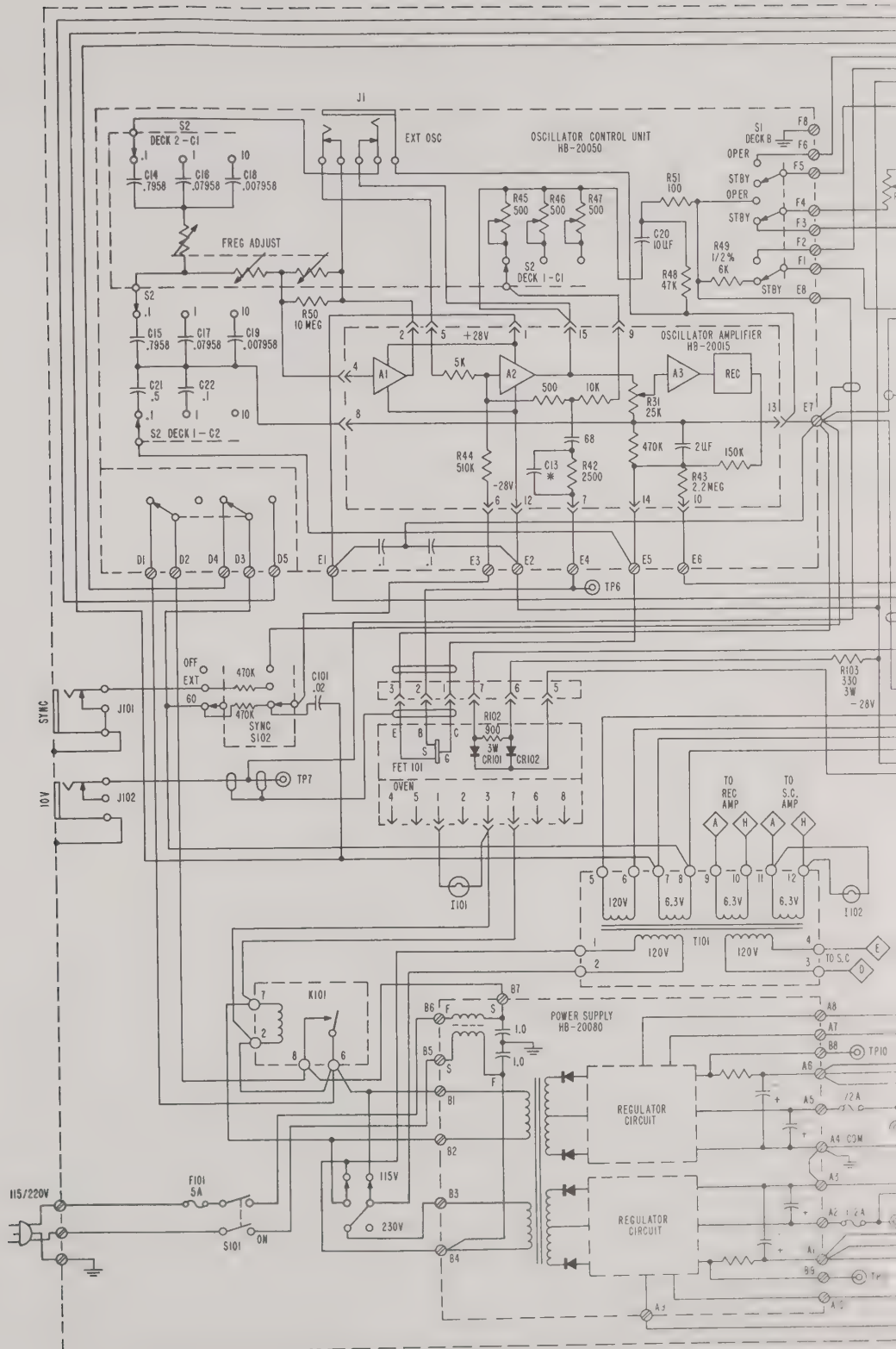
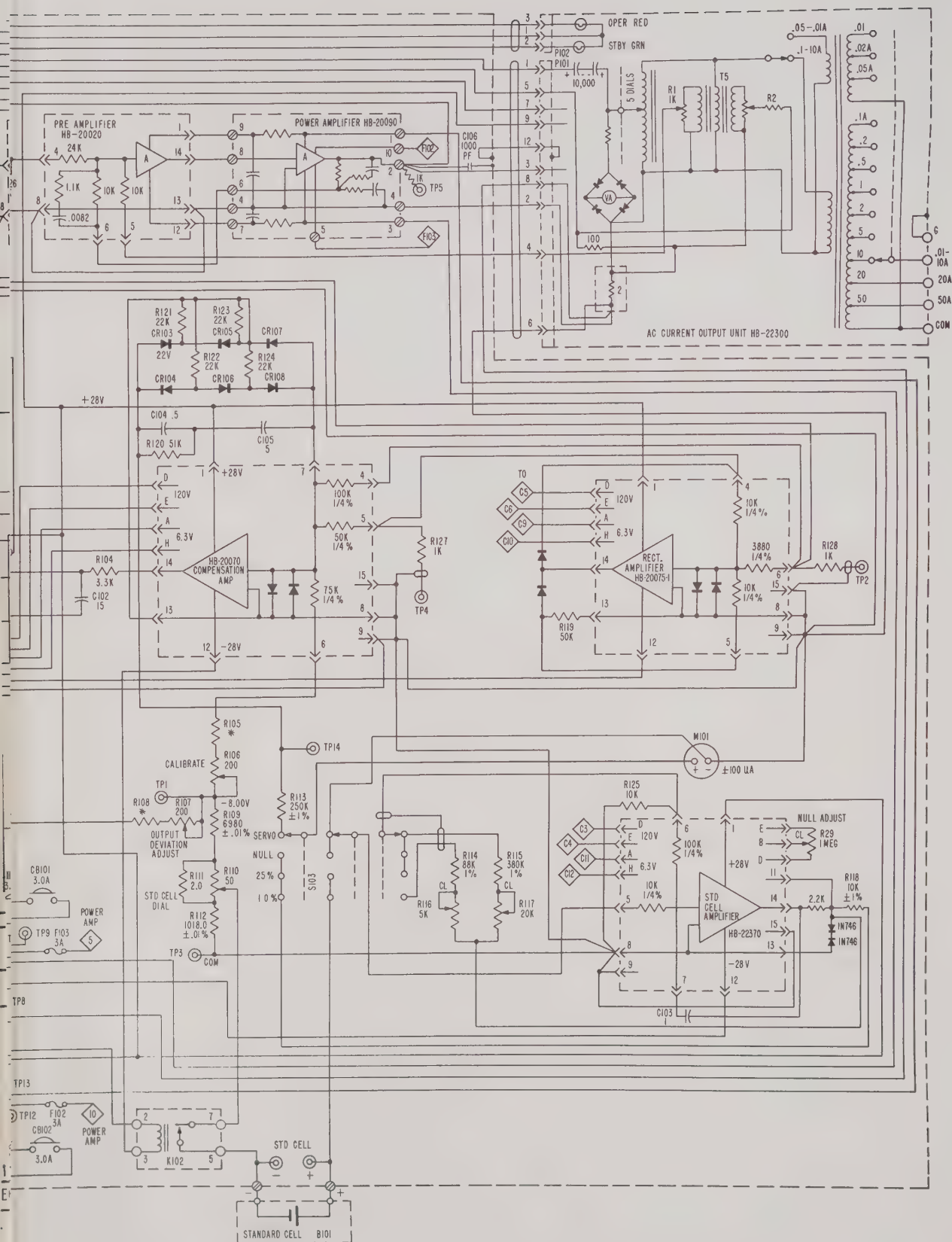
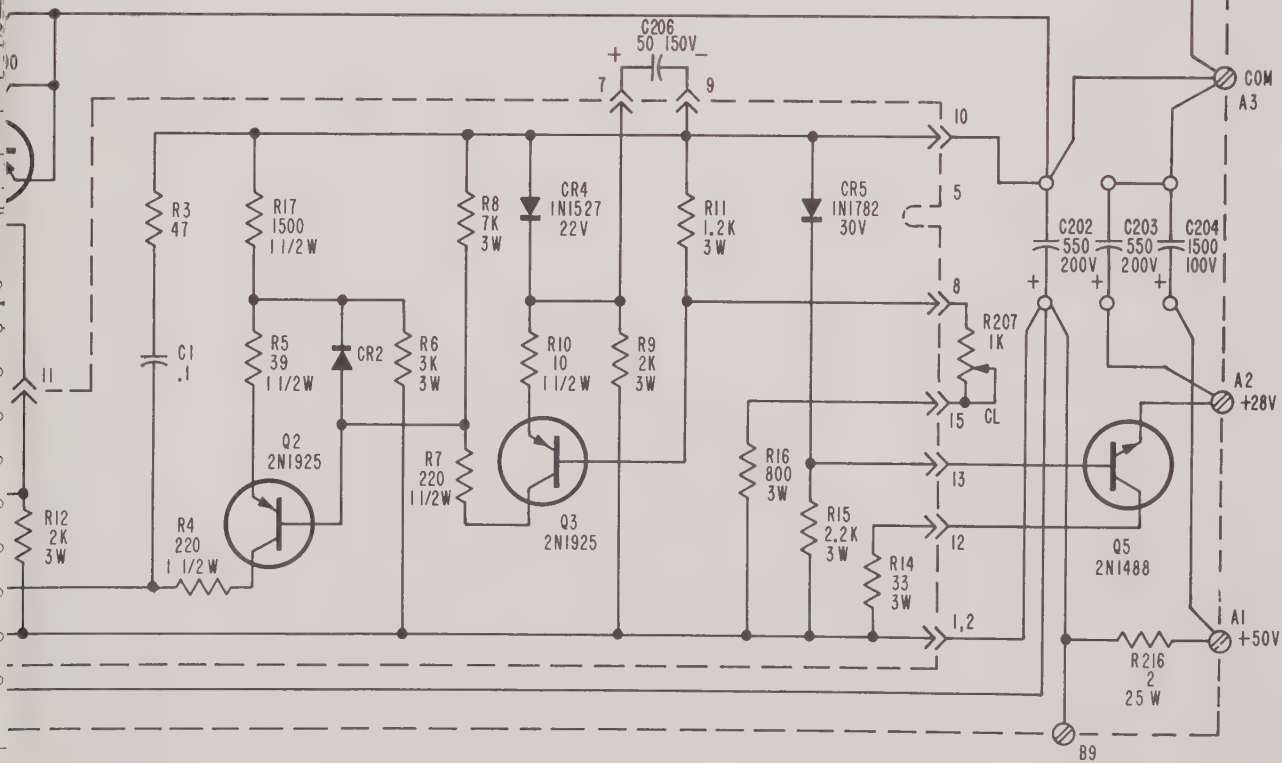
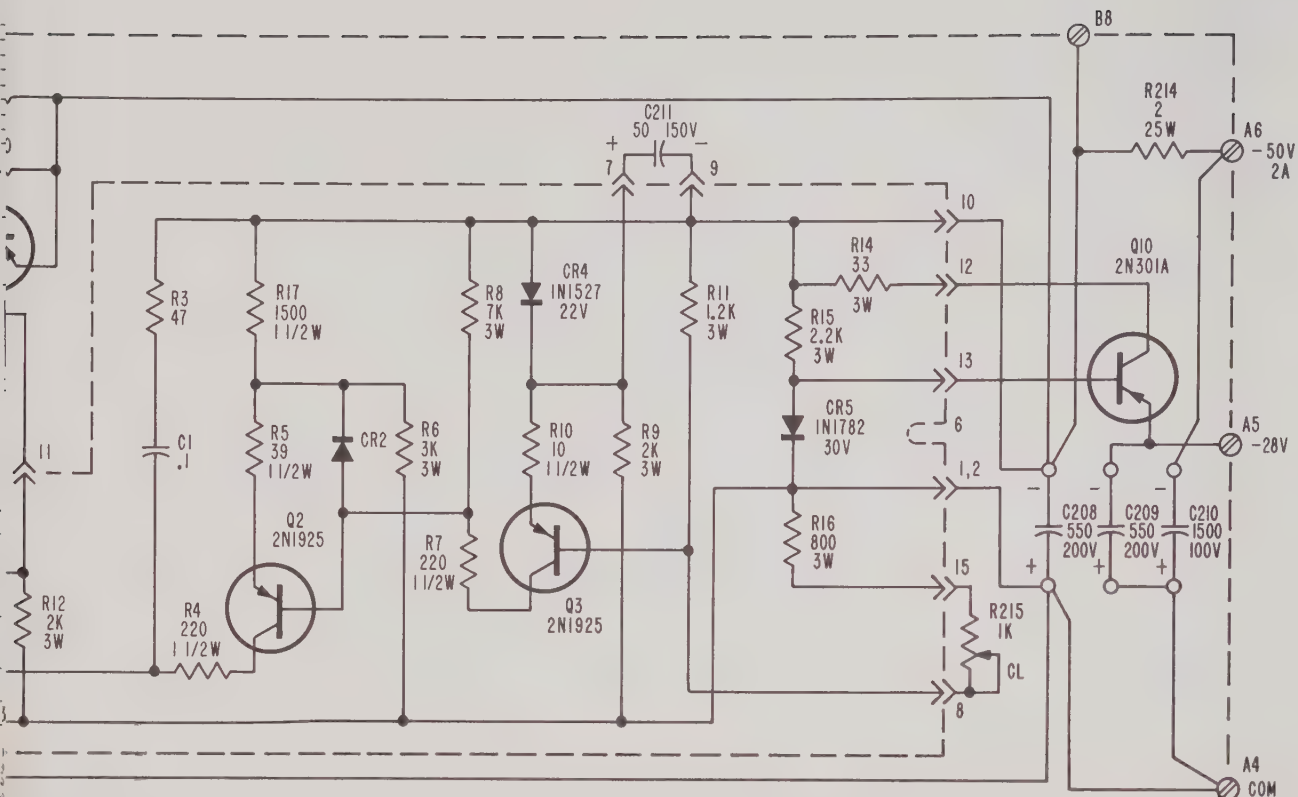


Figure 15.
Schematic Diagram of Current Standard Control Unit.





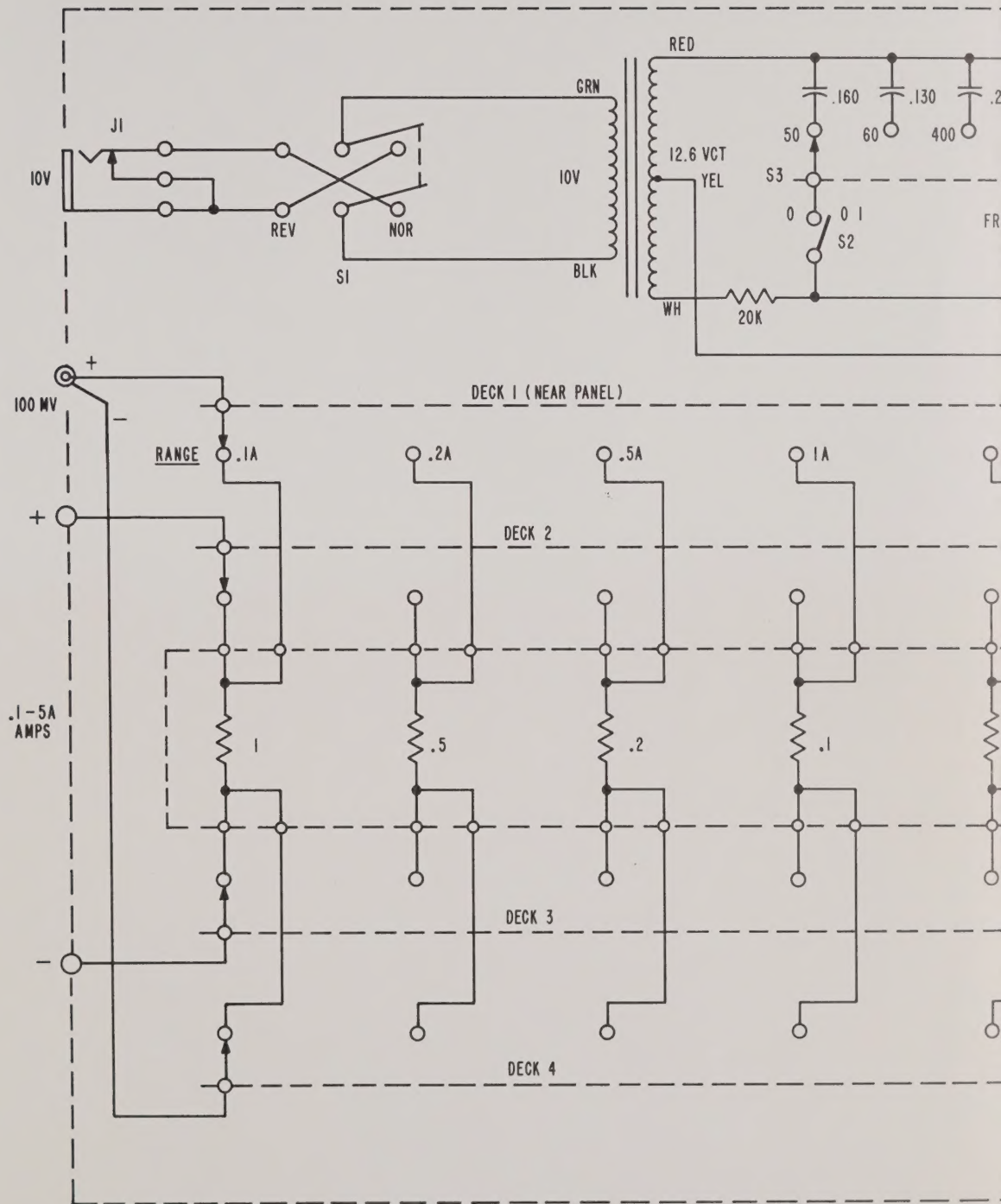
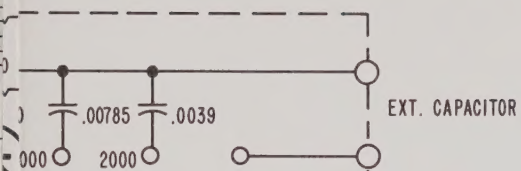
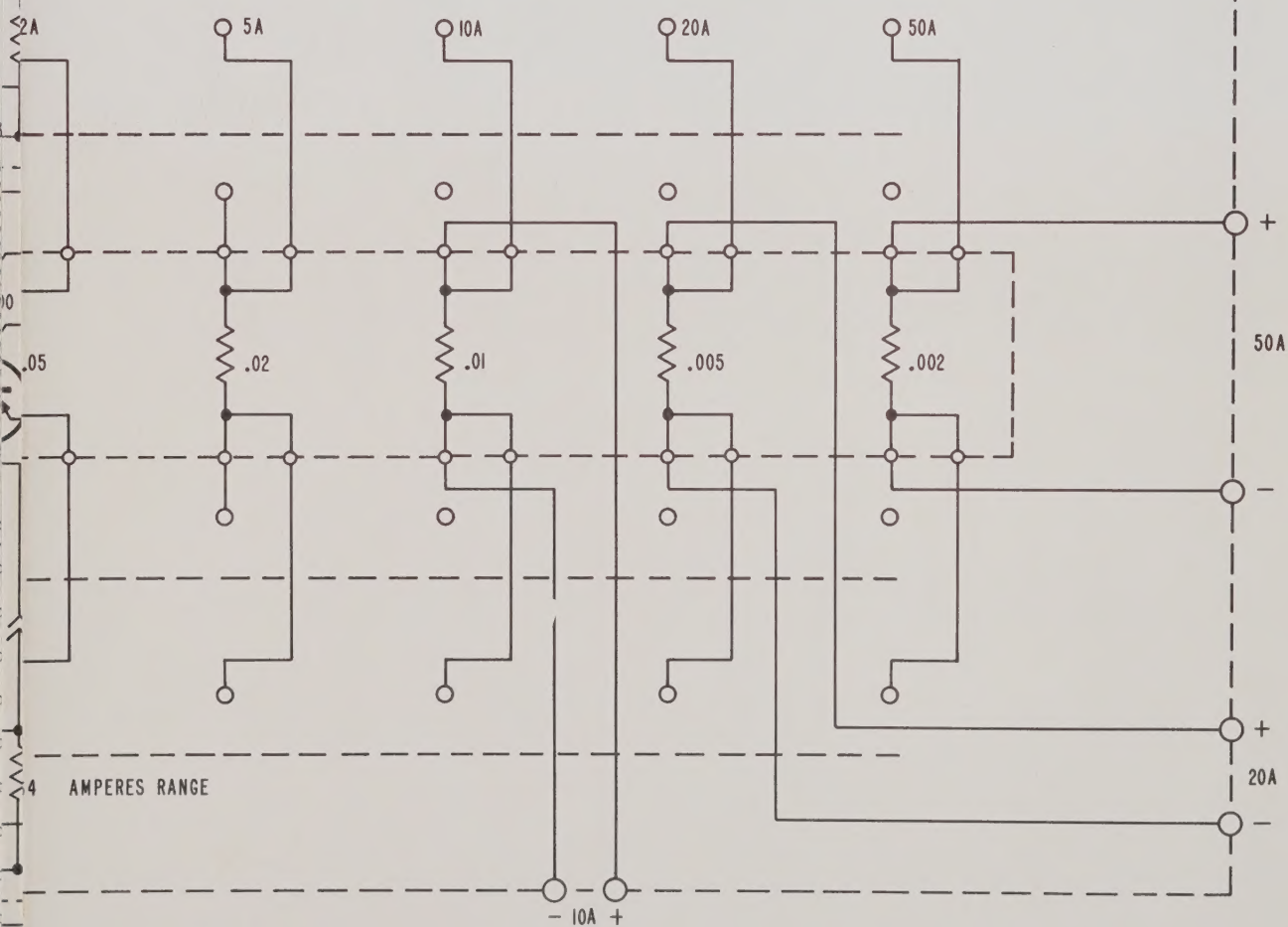
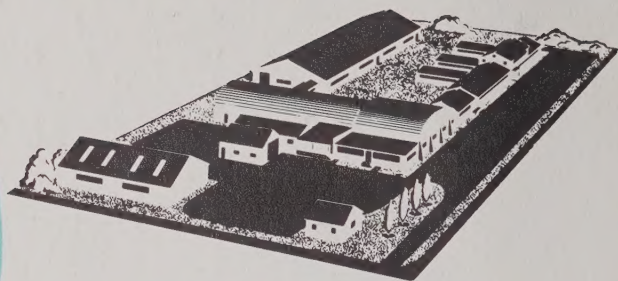


Figure 17.
Schematic Diagram of Watts Accessory Panel.



QUENCY RANGE





WARRANTY

The Model 100 System carries a warranty of 12 months from date of delivery for replacement of any part, except power transistors, which fails during normal operation or service. A deficient part should be returned to the factory, shipping charges prepaid, for replacement f. o. b. Boonton, N. J.

Radio Frequency Laboratories, Inc.
BOONTON, NEW JERSEY, U.S.A.

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